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Testimony concerning the Uniform Railroad Costing System. Presented to the Surface Transportation Board on April 30, 2009.

Ex Parte - 431 - Sub No.3

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Good Day. Board members and others, I wish to first thank you for giving me the opportunity to testify on the economic nature or the URCS and rail costing in general. This is a subject that I have been interested in since the early 1980's.

My name is C. Gregory Bereskin. I am Professor of Economics and Finance at St. Ambrose University in Davenport, Iowa, where I have been on the faculty since 1991. A copy of my academic VITA is included as an attachment. I received my doctorate from the University of Missouri in 1983. My dissertation consisted of building a bi-level model of railroad costs that demonstrated both that rail costs are decidedly non-linear and that they may be expected to follow the expectations of economic theory in terms of economies and dis-economies of scale.

Prior to joining St. Ambrose University, I was employed for a decade by the Atchison, Topeka, and Santa Fe Railway company. My first four years there were as economist in the Cost Analysis and Research section while the last six years were as Manager of Economic and Financial Analysis. In these capacities, I worked extensively with both the URCS and its predecessor, Rail Form A. In addition, I worked with the economics section at the Association of American Railroads on their responses to the Rail Accounting Principles Board.

I wish to stress, however, that I am here on my own volition and not in support of any group or individual. My primary concern is for costing to be done in a manner that fits within the basic theory of economics. To this end, I wish to speak to three topics which, I believe, are important relative to rail costing methodology, the non-linearity of railroad costs, the use of only two independent (or causal) variables in relation to "percent variable" analysis, and some of my findings relative to alternative methods of estimating railroad costs.

The first topic I wish to consider is the non-linear nature of railroad costs. Virtually every researcher who has evaluated the nature of rail costs since the mid 1970's has found that the cost structure is non-linear. This includes work by people such as Friedlaender and Spady; Caves, Christiansen, and Swanson; Ivaldi and McCullough; and Lee and Baumel; as well as my own work. I have provided a copy of my paper given at the 2008 Annual Meeting of the Transportation Research Forum which partially covers my research for the past almost 30 years. This later research shows that not only are railroad costs non-linear but that the current railroad market may be experiencing dis-economies of scale so that if the firms grow in size, the most efficient level of average costs will also grow. It is a logical extension that costs for additional traffic will also follow a non-linear pattern.

The second area that I wish to touch on concerns the use of only two independent causal variables in each of the regression equations that are developed to estimate "percent variable" factors. Two primary reasons exist for this situation. First, in the late 1930's when Ford Edwards was first developing Rail Form A, the time required to estimate a regression equation with only two variables (prior to computers) was such that, perhaps, one equation could be estimated by a person in a given day. Thus, it was necessary to keep the models simple so as to not create undue computational problems. If it was necessary to compare several regression models so as to choose the best one, this greatly increased the work load. Now, with the advent of computers, equivalent regression calculations may be done in a matter of nanoseconds so that an analyst has much more flexibility in the development of costing models. This degree of effort required to perform the calculations may also explain why the initial work was done using only a single year's cross section of data. We now have the capability to use a pooled data set of both time-series and cross-sectional observations, a situation that carries more importance now that there are only seven Class I railroads in the United States.

Third, the use of "percent variable" terms must also be called into question. There is no definitive statement within the economic literature as to whether the appropriate cost to be used in railroad regulatory analysis is an "average variable cost" or a "marginal cost." It is my belief that the "variable cost" that is implied by law is a most accurately a measure of "marginal cost." My reason for this conclusion comes from economic theory where the degree of markup (corresponding to market power) under the optimal markup pricing models indicates a markup over "marginal cost." Likewise, economic decisions are virtually always aimed toward decision making at the margin. A firm that is using "marginal cost pricing" where prices (rates) are set equal to marginal costs would be expected to experience little or no regulatory oversight. Under the economic theory of perfect competition, firms are forced by the market to set prices equal to marginal costs if they wish to maximize their profits.

If the assumptions of non-linearity of costs and the insufficiency of simple two variable models is accepted, then the basis and reliability of the current URCS models must be questioned. I have always believed that it is counter productive to argue that a model is incorrect without providing some guidance toward what may be a better methodology. In the case of the URCS, I would like to suggest two directions that the Board might take as based on my past research.

First, if it is desired to continue the cost breakdowns as currently structured, then the primary area of modification would be in the development of partial elasticity measures that could be used instead of the current, constant, "percent variable" factors for apportioning costs. An example of this methodology is covered in my 1989 Logistics and Transportation Review article " An Econometric Alternative to URCS (Uniform Railroad Costing System)" (copy attached). Under this methodology, each of the sixteen URCS expenditure categories is modeled using a translog functional form with multiple measures of both intermediate operating parameters and size (or capital goods). Partial elasticity measures may then be developed directly as partial derivatives of the translog form. These can then be algebraically manipulated using the total cost level of the expenditure classification to develop an estimate of either the marginal, incremental, or average variable cost associated with the expenditure category, as based on the actual operating parameters of the movement in question. Summing the marginal expenditure estimates for the sixteen categories will then yield an estimate of the marginal cost of the actual movement. This type of procedure will, thus, consider the total level of railroad operation and its effects on the cost of operation as well as the specific non-linear relations of the traffic movement itself.

A second possible methodology discussed in my 2001 Article in the Transportation Journal, "Sequential Estimation of Railroad Costs for Specific Traffic" uses a very similar methodology as mentioned above except with only one estimated equation for total costs. This may be a slightly less desirable technique in that the cost breakdowns are not made for sixteen categories of expenditures. The benefit lies in the amount of statistical analysis that is necessary to develop a single translog model rather than sixteen.

Each of these methods of estimating railroad costs has several major advantages over the current simple URCS model. First, the models explicitly include the potential for railroad costs to be non-linear. Second, the methodology allows for the estimation of both marginal and average variable costs through a simplifying assumption of equal percent changes in activities.

Finally, in the current era where there is evidence that the railroad industry may, in fact, be experiencing dis-economies of scale, these methods allow for much more reasonable estimates than would a model that assumes continuously declining average and marginal costs.

I thank you for your time allowing me to present my testimony and would be more than willing to answer any questions you may have.

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EDUCATION:

Ph.D. 1983 University of Missouri-Columbia (Economics) Concentration in economic theory, public finance, and econometrics Dissertation: "A Bi-Level Model of United States Railroad Costs," Advisor: Dr. John P. Doll

M.A. 1972 University of Cincinnati (Economics) Concentration in economic theory, monetary economics, and mathematical economics

B.A. 1970 University of Cincinnati (Economics) Minor areas in Physics and Mathematics

Additional Graduate Course - Northwestern University - Logistics Management

CURRENT EMPLOYMENT

St. Ambrose University, Aug., 1991 to Present

Professor of Economics and Finance, College of Business Graduate Programs 2000-Present
Associate Professor of Economics and Business 1991-2000 — Tenure granted 1996
Teaching MBA level Managerial Economics, Macroeconomics, Managerial Finance, Operations Management, and Logistics, (Developed the MBA course in Business Logistics.)
Teaching undergraduate level Principles and Intermediate Economics (both Micro and Macro).

OTHER EMPLOYMENT

Roy R. Fisher, Inc. May 2006 to Present

Commercial Real Estate Appraisal including right of way analysis.

C. G. Bereskin & Associates, Aug., 1989 to Present

Provided economic and transportation consulting services as appropriate to the needs of clients.
Concentration in econometric costing, forecasting, and logistics and transportation analysis.
Clients have included national and state governments and private companies.

University of Iowa, Public Policy Center, Summer, 1994

Project Assistant
Work on funded research projects in Transportation and Transportation Economics.

The Atchison Topeka and Santa Fe Railway Co., 1980 to Aug. 1989

Manager: Economic and Financial Analysis, 1984 to Aug. 1989

Coordinated the economic and financial analysis activities of the Cost Analysis and Research Department including analysis of the economic validity of various railroad costing systems, forecasting input prices and transportation activity, analysis of escalation clauses in transportation and joint facility contracts, developing the economic environment statement for the long-range plan, and coordination of internal rate of return and buy/lease analysis for railroad capital projects.

Economist: Cost Analysis and Research, 1980 to 1984

Provided economic analysis and forecasting expertise as needed by department..

Chase Econometrics/Interactive Data Corp., 1978 to 1980

Economist and Technical Consultant

Advising clients on problems related to economic analysis, developing econometric forecasting models, and training clients in the use of a proprietary computer language.

University of Northern Iowa, 1975 to 1978

Instructor, 1975 to 1977
Assistant Professor, 1977 to 1978

Teaching: Principles of Economics, Managerial Finance, and Quantitative Methods in Business.

Northwest Missouri State University, 1974 to 1975

Interim Assistant Professor

Teaching: Managerial Economics (MBA), Principles of Economics, and Business Policy.

PUBLICATIONS and PRESENTATIONS

Railroad Economies of Scale, Scope, and Density Revisited, Forthcoming, Journal of the Transportation Research Forum, Summer 2009

Railroad Cost Curves Over Thirty Years: What Can They Tell Us? Presented at the 2008 Annual meeting of the Transportation Research Forum, Spring 2008 (Best Paper award winner)

Railroad Capital Stock Changes in the Post-Deregulation Period. Journal of theTransportation Research Forum, Spring 2007

Have Railroad Mergers Resulted In Cost Savings? A Backward and Forward Looking Counterfactual Analysis. Paper presented at the Second Conference on Railroad Industry Structure, Competition, and Investment. Held at Northwestern University, Evanston, Il. Oct. 8-9, 2004

Have Railroad Mergers Resulted In Cost Savings? A Counterfactual Analysis. Presented at the 2004 meeting of the Transportation Research Forum

Economies of Scale Scope and Density Revisited. Presented at the 2003 meeting of the Transportation Research Forum

Railroad Capital Stock Changes in the Post-Deregulation Period. Submitted to the Journal of the Transportation Research Forum. Presented at the March, 2002 Missouri Valley Economics Assn. Meeting

Econometric Estimation of Railroad Costs: Implications for Policy. Seminar presented at Northwestern University, November 2002

Estimation of Costs Effects for Potential Trans-Continental Railroad Mergers, Review of Transportation Economics: Vol 6, Transportation After Deregulation. Also presented at the 2001 meeting of the Missouri Valley Economic Association.

Sequential Estimation of Railroad Costs for Specific Traffic, Transportation Journal, Vol. 40/No,3 Spring, 2001 pp 33-45. Also presented at the 2000 Midwest Economics Association Meetings.

Estimation of Maintenance of Way Costs for U.S. Railroads Following Deregulation, Transportation Research Record #1707, Oct. 2000; pp13-21. Also presented at the 2000 Transportation Research Board Annual Meeting, Jan., 2000.

Regulation, Deregulation, and ? Re-regulation Paper for Transportation Research Board Compendium for the year 2000. Committee A1B06 paper.

Estimation Of The Effects of Post-Deregulation Mergers on Railway Costs, Presented at the ASSA meetings Chicago Il. January, 1998

Estimation Of The Rate of Growth in Productivity in Post Deregulation Railroads; Transportation Journal, vol 35/no. 4 summer, 1996: Earlier version presented at the annual meeting of the Western Economics Association International, Seattle, WA. July, 1991.

Analysis of Post Deregulation changes in Railroad Capital Stocks, Presented at the annual meeting of the Western Economics Association International, Vancouver, BC, Canada, July, 1994.

An Econometric Alternative to the URCS, The Logistics and Transportation Review, , June, 1989, pp. 99-128. Also presented at the Allied Social Sciences Associations, New York, December, 1988.

An Examination of the Structure of Railroad Costs, Presented at the 1987 meeting of the Missouri Valley Economic Association.

Alternative Estimation Techniques for Rail Cost Functions, Paper presented to the Association of American Railroads Cost Analysis Organization Meeting, March 1983.

MEMBERSHIP IN PROFESSIONAL ORGANIZATIONS

Transportation Research Forum

President 2003-2004
Executive Vice President 2001-2003
Vice President-Program 2000-2001
Vice President-Program 1999-2000
Vice President Chapter Relations 1997-1999
National Council Member (at large) 1995-1997

Transportation Research Board

Chair, Committee on "Surface Freight Transportation Regulation" November, 1998 to 2002

American Economics Association

and the Transportation and Public Utilities Group of the American Economics Association

American Real Estate and Urban Economics Association

The Appraisal Institute

Midwest Economics Association

National Association of Business Economists

Nominated for Board of Directors 1988, Regional Coordinator-Regional/Utility Round Table.
Chicago Chapter President, Vice President, Secretary/Treasurer.

WORK IN PROGRESS

Econometric Estimation Of Costs for Specific Railroad Freight
Economies of Scale, Scope, and Density Revisited: - The Post-Deregulation Railroads.
Prediction of Changes in Railroads' Cost Structures Following Mergers in the Post Deregulation Period
Examination of the Effects of Transportation and Logistics Costs on International Trade Flows
Estimation of the Effects of Heavy Wheel Loading on Railway Maintenance of Way Costs

Currently Developing a course in Real Estate Economics and Finance

OTHER PROFESSIONAL ACTIVITIES

Licensed Associate Real Estate Appraiser in Iowa

Session Chair: TRF Annual Meeting, Evanston, IL. Mar., 2004
Session Chair: TRF Annual Meeting, Washington, DC Mar., 2003
Referee: Logistics and Transportation Review (Transportation Research E).
Discussant: MEA. Meeting; March, 2000, Chicago.
Session Chair: TRB Annual Meeting, Washington, DC Jan., 2000
Session Chair: TRB Annual Meeting, Washington, DC Jan., 1999
Session Chair: TRB Annual Meeting, Washington, DC Jan., 1998
Session Chair: TRF Annual Meeting, Montreal Sept., 1997
Session Chair: TRB Annual Meeting, Washington, DC Jan., 1997
Discussant: MEA Meeting; March, 1996, Chicago.
Discussant: WEAI Meeting; July, 1994, Vancouver, BC, Canada.
Discussant: WEAI Meeting; July, 1992, San Francisco, CA.
Session Chair: WEAI Meeting; July, 1991, San Francisco, CA.
Discussant: ASSA Meetings; December, 1990, Washington DC.
Referee: Journal of the Transportation Research Forum.
Session Moderator: AAR Cost Analysis Organization Meeting, May, 1988.
Session Moderator: Joint session between Chicago Association of Business Economists and the Midwest Business Economists Association, November 1988

RAILROAD COST CURVES OVER THIRTY YEARS: WHAT CAN THEY TELL US?

A paper presented to the 2008 Annual meeting of the Transportation Research Forum

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C. Gregory Bereskin, Ph.D. has been involved with economic costing models of railroad traffic for over 25 years. He is currently employed as Professor of Economics and Finance in the graduate programs at St. Ambrose University in Davenport, Iowa Prior to his current position, he was Manager of Economic and Financial Analysis at the Atchison Topeka and Santa Fe Railway where he worked on costing, regulatory, and financial problems. He received his Ph.D. in Economics from the University of Missouri-Columbia (writing on railroad costs) and his MA and BA degrees in economics from the University of Cincinnati. He is currently working in two primary areas, developing models that apply econometric methodology to costing of railroad traffic and studying the relationship of transportation services to real estate prices.

RAILROAD COST CURVES OVER THIRTY YEARS WHAT CAN THEY TELL US?

C. Gregory Bereskin, Ph.D.
St. Ambrose University

ABSTRACT

Over the past thirty years, the railroad industry has undergone many changes. Firm size has increased, the total number of miles-of-road operated by Class I railroads has decreased and productivity has climbed tremendously so that the cost of moving rail freight has declined. Much of the industry's gains are as a result of deregulation. but some of them are simply the result of the changing nature of the firm. By looking at simulations of railroad costs, we are able to tell much about economies of scale and density within the industry.

This paper looks at railroad cost curves that have been developed, for the years 1976, prior to deregulation, 1990, approximately fifteen years later and 2005, through the use of different econometric models. In addition, cost curves are developed for each of the class I railroads in 2005 as support of the models. These curves are compared in order to develop implications for economies and diseconomies of scale both as the industry has evolved and potentially into the future.

One conclusion of the paper is that over a thirty-year industry, even though the industry changed substantially in terms of the optimal size of the railroad firm, the long-run optimal firm size has not changed a lot. In addition, there appears to be little economic justification for future mergers if they are evaluated in terms of economies of scale. Finally, some firms may still have the ability to make gains in terms of economies of density but that this is not true for all firms. In fact, at least one firm is shown to have estimated short-run marginal costs above average costs so that simple increases in traffic levels are not necessarily desirable.

INTRODUCTION

Rail freight movements, like most transportation services, are subject to a number of technological characteristics that make costing of specific traffic a complex process. Among these restrictions are conditions of joint production, economies of scale, scope, and density, and a lack of data on specific expenditures as related to individual freight movements. As a result, historic rail costing may be been divided into two general areas. One is movement costing which has traditionally involved the use of accounting based allocative costing models such as the Uniform Rail Costing System (URCS), originally developed by the Interstate Commerce Commission for use in regulatory hearings and, currently, in use by the Surface Transportation Board. The URCS relies on simple linear relationships in order to evaluate specific railroad costs. This costing system has not been updated since the 1980's. The URCS applies "percent variable" estimates, developed within two variable (output and size) regression equations, in order to allocate expenses incurred by the railroads. One problem with this methodology is the assumption that all of the percent variable estimates must be between zero and one. As a result, the model contains an implicit assumption that the industry has continuing economies of scale and to output (density).

Bu the mid 1970's the idea that the industry must be heavily regulated had eased and a number of researchers began examining the nature of rail costs with an eye toward deregulation. The new models of rail costs were much more oriented toward economic inquiry rather than for use as regulatory costing tools. As such, they were aimed at examining whether the industry could be characterized by linear relationships and whether there had been gains in productivity over the prior periods. Models such as those of Caves, Christensen, and Swanson (1980, 1981a, 1981b, 1981c): and Bereskin (1996) looked at productivity growth while those Spady (1979); Spady and Friedlaender (1976); Friedlaender and Spady (1980); Bereskin (1983); Barbara, Grimm, Phillips, and Seltzer (1987); and Lee and Baumel (1987) were more closely concerned with general shape of the cost function and the resulting economies of scale, scope, or density. Oum and Waters (1996) discussed the status of transportation cost study advances over the prior two decades and have described various refinements in the modeling methodology that has allowed researchers to further test for economies of scale and scope as well as productivity growth. All of these studies generally agree in their conclusions that the railroad industry has been achieving productivity gains both over time and through mergers and that rail costs are decidedly non-linear in nature.

The Barbera, Grimm, Phillips, and Selzer study (1987) is primarily concerned with directly estimating the cost relation in order to test hypotheses concerning economies of scale and density in the industry and thus estimates only the cost function. Alternatively, Lee and Baumel (1987) deals with a simultaneous estimation of both the cost and demand function for rail services for the years 1983 and 1984, where the translog function is used as a Taylor series approximation to an unknown underlying cost function while the demand function, being a derived relationship, is modeled as a Cobb-Douglas structure. Both studies find that economies of density exist although the estimates obtained by Lee and Baumel (1987) are significantly lower than for Barbera, Grimm, Phillips, and Selzer (1987). Additionally, both agree that returns to scale appear to be insignificant. One problem with the analysis is that the proxy variable used for the size of capital stock in each of these studies is miles-of-road, an approximation that may introduce a bias into the results as miles-of-road fails to address the condition and level of quality of the roadway capital.

More recently, in an effort to determine the effects of density and railroad mergers on costs, Ivaldi and McCullough (2001) have estimated a translog model of short-run railroad costs using different types of car-miles as a measure of traffic. They find three implications for railroads that are of interest here. First, that Class I railroads have returns to density. Second, that there are significant second order effects among railroad operational outputs. Third, that there are vertical cost relationships between freight operations and infrastructure operations. Alternatively, Bitzen and Keeler (2003) have, in an effort to explain productivity growth in the deregulated industry, applied both miles-of-road and developed price indices for right-of-way capital structure and for equipment capital to explain the effects of capital within railroad costs. They conclude that railroad productivity growth has continued at much the same rate as it grew in the decade immediately following deregulation. Bereskin (2007) has also examined the railroad industry using the translog function but was much more concerned with the looked at railroad costs with an eye toward both economies of scale and costing of actual traffic on the railroad system.

One problem with these models is that. while they examine economies using quantitative methods, they do not take the extra step of actually examining the overall shape of cost curves and whether there was an optimal size for a railroad firm. Only Bereskin (1983, 2007) actually attempts to draw the curves and make implications toward where economies of scale end and diseconomies take over. This paper will look at the models of Bereskin (1983, 2007) and compare the implication for railroad scale economies/diseconomies between 1976 and 2005.

II. METHODOLOGY

In his 1983 study, Bereskin found that the railroad industry appeared to have the potential for significant gains from size. The model used translog functions to model expenditures in each of the five major classifications of railroad expenditures: maintenance of way and structures, maintenance of equipment, transportation, traffic expenditures, and general expenditures. (By 2005, the expense accounts had been changed so that only four categories were used: maintenance of way and structures, maintenance of equipment, transportation, and general expenditures). Only two primary independent variables, gross-ton-miles and miles-of-road-operated were used in each equation although dummy variables for each firm and time were also included as were price indices for wages and supplements, materials and supplies, and fuel.. All of the models for individual sector expenditure were then embedded into an additional translog function for overall expenditures. A primary assumption that allowed this methodology was that the industry expenditures were, in effect, separable into a "tree" model structure where each sector was allocated funds, which were then spent efficiently within that sector. This gave a very general model that was then simulated to develop an overall structure of costs as output varied around the average level for an average railroad in the industry.

In the more recent model, Bereskin (2007b), a single translog equation is used to model the industry rather than multiple embedded equations. However, the recent model is more general in that, rather than using miles-of-road as a proxy for capital stock, it uses separate estimates of capital for equipment and roadway developed using the methodology of Bereskin

(2007a). Five intermediate measures of output, gross-ton-miles, train-miles, car-miles, thousands-of-switching-hours, and thousands-of-horsepower-miles are used rather than only gross-ton-miles.[1] Three price indices, those for fuel, wages and supplements, and materials and supplies are also included in the model. [2,3,4]

The translog equation is then:

(1)

$$\ln Q_i + a_{k_1} \ln K_1 + a_{k_2} \ln K_2 + \sum_{j=I}^{M} ¿\, a_j \ln P_j^1$$

$$\sum_{l=I}^{2} ¿\, b_{ik_1} \ln Q_i \ln K_l$$

$$\sum_{l=I}^{N} ¿\, ¿ + \sum_{j=I}^{M} ¿ \sum_{n=I}^{2} ¿\, b_{jk_n} \ln K_n \ln P_j^1 + \sum_{i=I}^{N} ¿\ SUMFROM\ j =$$

$$M$$

where the Q terms are the five intermediate measures of output, the K terms represent the two capital stock measures, and the price measures are indicated by the P terms. Use of the translog function requires that certain restrictions are met in order to insure that the cost function is well behaved as required by economic theory. One implication then is that the cost function should be linearly homogeneous. As such, the regression model requires restrictions on the coefficients within the cost equation. These restrictions are

(2a)

$$\sum^{n} ¿\, a_j = I$$

(2b) $$\sum_{j=1}^{M} \text{¿} b_{jk} = 0 \quad \_ \; k = K_k \; ; \; i=1,\ldots,N$$

¿

The a_j terms

correspond to the coefficients on the linear price terms of the translog equation and the b_{jl} values are the coefficients for the quadratic price variables in the translog specification. Symmetry conditions indicate that $b_{jl} = b_{lj}$. Development of values for average and marginal costs, follow the methodology in that and earlier work by Bereskin.

Like the 1983 study, the model is simulated, allowing the output and, in this case capital stock variables, to vary in order to estimate cost curves for both 1990 and 2006. (In the 1983 study miles-of-road rather than capital stock varied) To maintain some consistency with the earlier study, a geometric average railroad is used with gross-ton-miles as the weighting factor and when output varies, all of the intermediate measures are changed in the same proportion..

III. RESULTS OF THE MODELS

Railroads in 1976

Figure 1 is a copy of Figure 5.2.1 from the Bereskin (1983) study. The graph shows the short-run cost relationships (average and marginal costs in cents per gross-ton-mile) developed for a geometric average firm in the industry where gross-ton-miles was the weighting factor. In this case, the average firm was seen to have 9,915.08 miles-of-road-operated. Average gross-ton-miles were 28,814,260. Given that miles of road are held constant the model shows distinct economies and diseconomies to output (density).

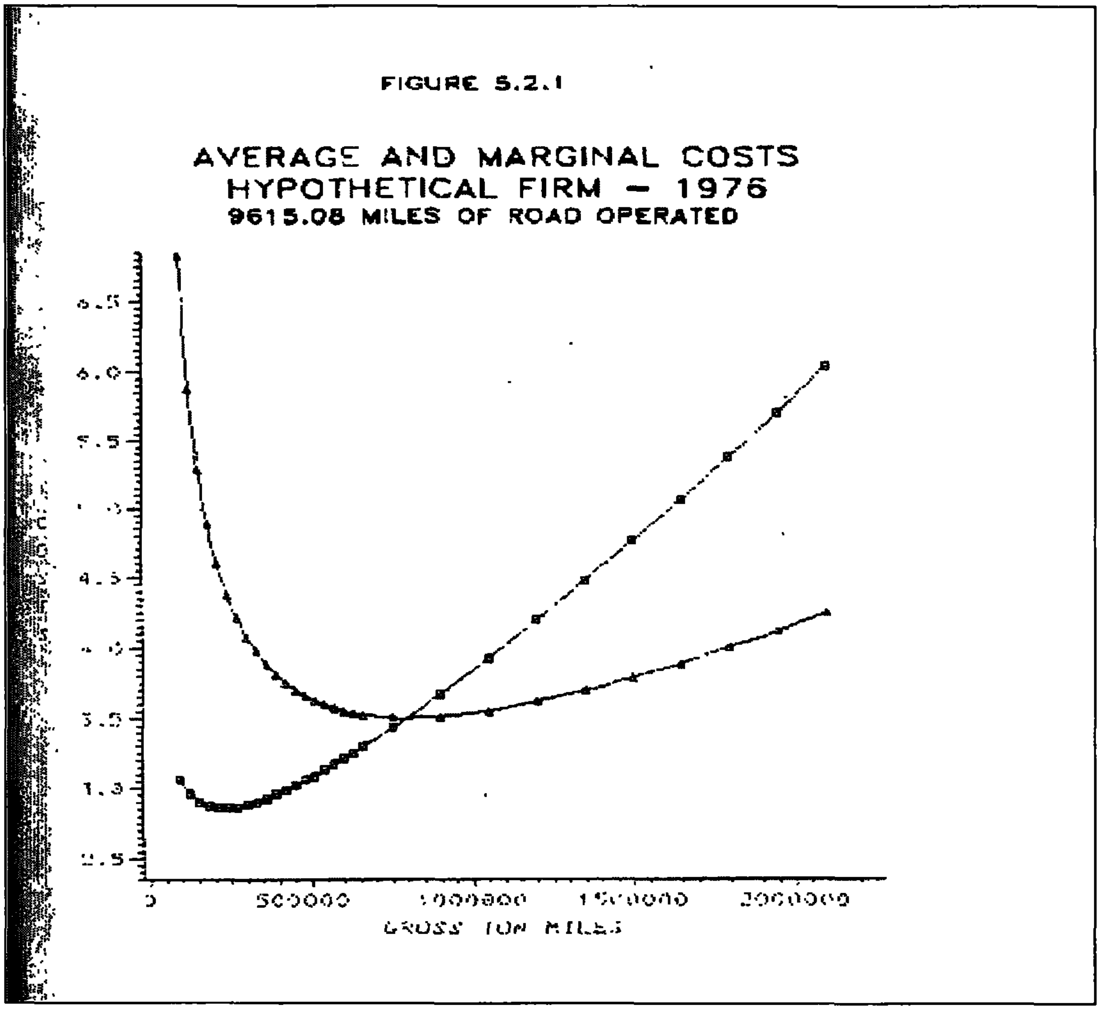
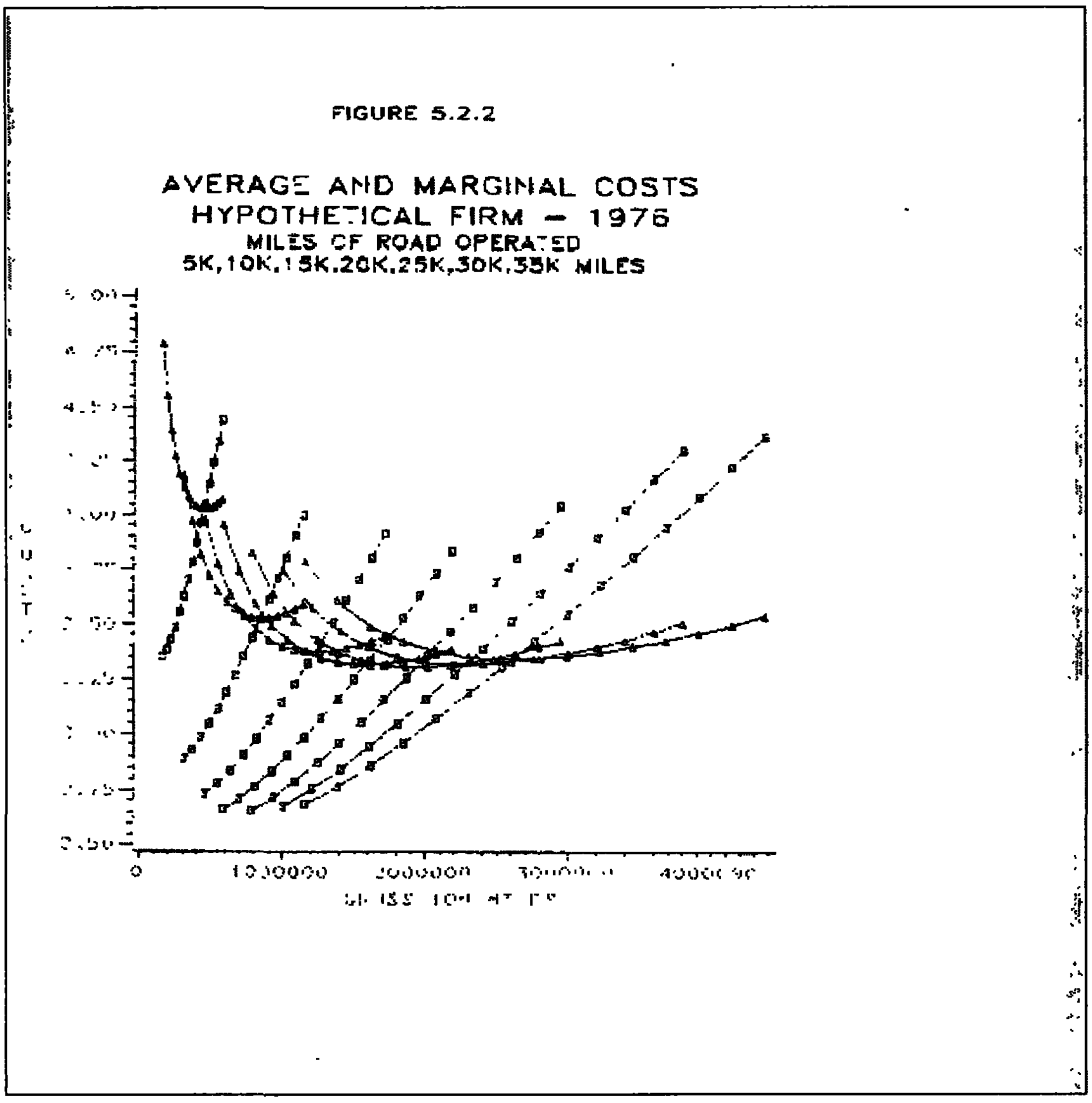


Figure 1

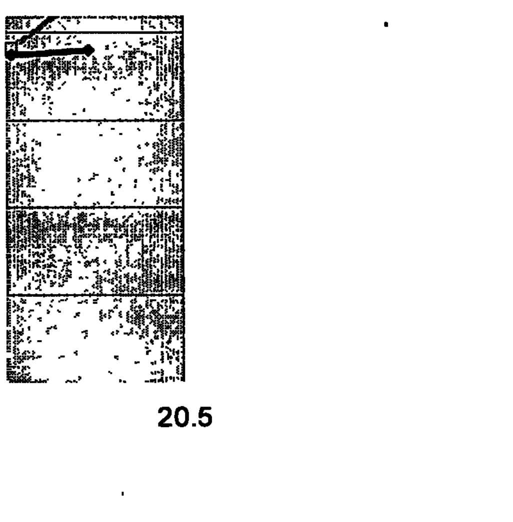
Figure 2, is the equivalent long-run cost curve diagram (figure 5.2.2 in the original paper). For this diagram, the number of miles-of-road was allowed to vary from 5000 to 35,000 in increments of 5000 miles. The diagram shows distinct economies of scale for the smaller size railroads. However, for larger size railroads, diseconomies appear to develop. Examination of the data included in the report indicates that the lowest average cost figure from the simulations is at 3.27308 cents per gross-ton-mile for the 25,000-mile-of-road railroad. The lowest average costs for the 30,000-mile and the 35,000-mile railroads are 3.28735 and 3.31430 respectively. This indicates that a railroad in the neighborhood of 25,000 miles-of-road was the potentially the most efficient size in 1976.

Figure 2



The 1990 Railroad

For 1990, the model of Bereskin (2007b) was simulated at 1990 levels for all relevant variables. In order to accomplish this, weighted averages of the variables were computed. And used to simulate the model. By 1990, the railroad industry had undergone degree of consolidation. The number of Class I railroads had decreased to 14, the average miles-of-road-operated had increased to 16,527, and the average gross-ton-miles had increased to 142,150,000. The cost curves for this period shown in figures 3 and 4 however indicate that the optimal size railroad had not changed significantly although the cost of moving traffic had decreased significantly. Figure 3 shows the short-run cost curve at the average capital stock for the industry in 199 with output varying from 0.8 to 1.6 times the actual weighted average levels for the five


20.5

intermediate output measures. The marginal cost curve is shown to pass through the average cost curve at just slightly under 1.5 times the average activity level. This indicates that there is the potential for slight reductions in average cost as traffic increases.

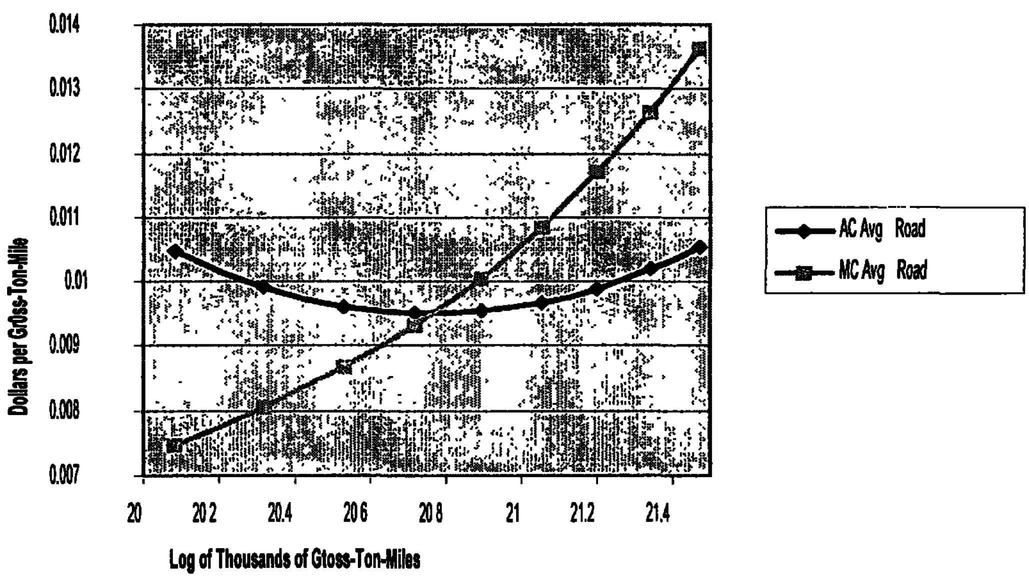
The long run cost curves (Figure 4) show a relationship that appears to have not changed significantly since 1976. The lowest of the various short-run cost curves appears to be at a multiple of about 1.5 times the average capital stock values. This roughly corresponds to a railroad size of approximately 25,000 miles-operated (1.5 x 16,527 = 24,790), not significantly different than the 1976 size. While the industry had consolidated and moved toward the most efficient railroad size, the optimal size did not change much, even if the cost per gross-ton-mile had decreased substantially.

The 2005 Railroad

Results of simulation of the model for the year 2005 were reported in Bereskin (2007b) but are replicated here as well for comparison. The geometric average firm size had grown to 27,642.1 miles-of-road with gross-ton-miles of 823,357,000 gross-ton-miles. The simulated short and long-run cost curves for this firm are shown below in figures 5 and 6. Figure 5 shows the short-run cost curve at the average capital stock for the industry in 2005 with output varying from 0.8 to 1.6 times the actual weighted average levels for the five intermediate output measures. The marginal cost curve is shown to pass through the average cost curve at just slightly over 1.1 times the average activity level. This indicates that, for the firm as defined here, there is the potential for slight reductions in average cost as traffic increases.

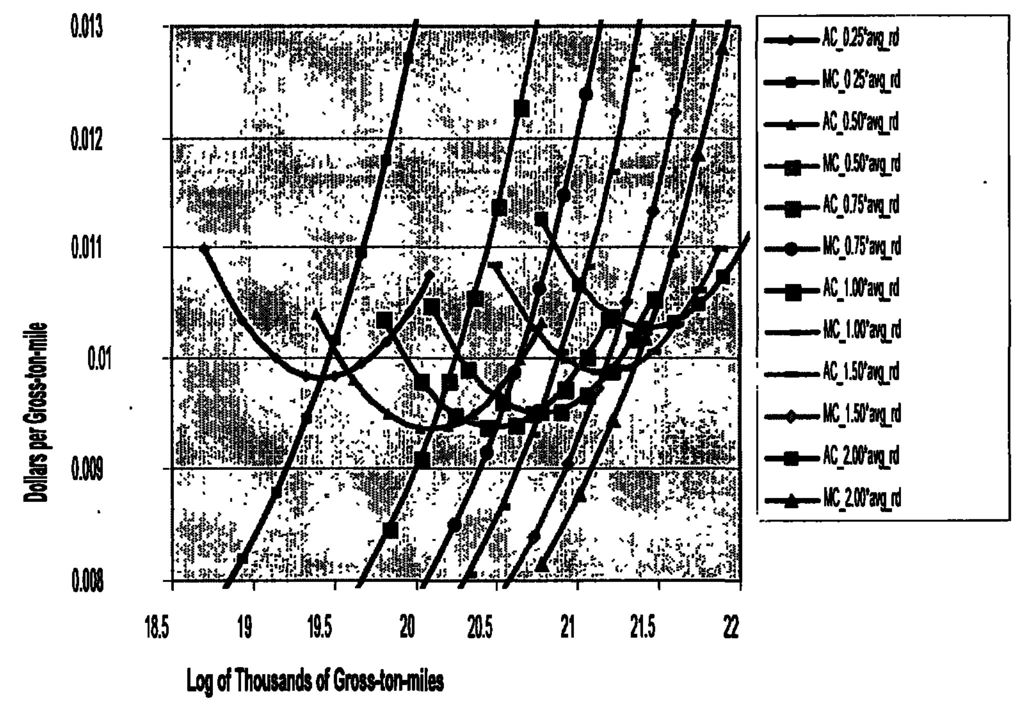
The long run cost

Figure 5
Average and Marginal Cost Estimates
Geometric Average Railroad 2005
(output multiplied from 0.8 to 1.6)



simulation where output levels are allowed to vary from 0.8 to 1.6 times average and where capital stock (and the consistent output levels) is allowed to be either 0.25,0.50, 0.75, 1.00, 1.50, or 2.00 times the weighted average level (Figure 6), shows results that are reasonably consistent with the earlier situations.

Figure 6
Average and Marginal Costs
Geometric Average Railroad 2005
(output multiplied by 0.8 to 1.6)



The "long-run" minimum cost point for average cost appears to be at about 0.75 times the weighted average level. This would correspond to a weighted average railroad of about 21,000 miles of road (0.75 x 27,642 = 20731). This is slightly smaller than for the 1976 and 1990 simulations, but given the differences in the models it is not impossible.

Of importance here is that there appear to be diseconomies of scale in the railroad industry, at least for the larger firms. However, even with these diseconomies, it is important to note than the minimum average cost per gross-ton-mile has declined to just under one-cent. This is in agreement with all of the other economic research that indicates that the industry has been experiencing significant productivity growth over the past thirty years.

IV. INDIVIDUAL RAILROADS

The results of the models reported above indicate that the firms n the industry may already have grown too large and are at a point of diseconomies. But does this hold for each of the individual railroads? In order to examine this question, the Bereskin (2007b) model was simulated for each of the individual Class I railroads. In this case, the railroads were allowed to vary from 0.50, 1.00, 1.50, and 2.00 times their estimated capital stock levels, with output between either 0.6 and 1.6 times size and actual output or 0.8 to 1.8 times size and actual output as measured by the intermediate measures and times the capital stock increase. The model indicates that the "big four" railroads, the Union Pacific, Burlington Northern and Santa Fe, the Norfolk Southern, and the CSX Transportation are all in the range of diseconomies. On the other hand, the three smaller railroads, the Kansas City Southern, the CNGT system and the Soo Line should all be in areas with constant or increasing economies of scale.

The Big Western Railroads

Unlike the situation for the big eastern railroads, the two big western railroads, the Union Pacific and the Burlington Northern and Santa Fe have much less to gain in terms of increased density and are already at a point of diseconomies

BNSF:

The simulation of the model for the BNSF (Figure 7) indicates that the firm has reached the point where not only is it experiencing diseconomies of scale but also appears to be at a point where marginal costs have risen above average costs. This occurs at a point (as indicated in Figure 7) where output increases above 0.8 times the current traffic makeup.

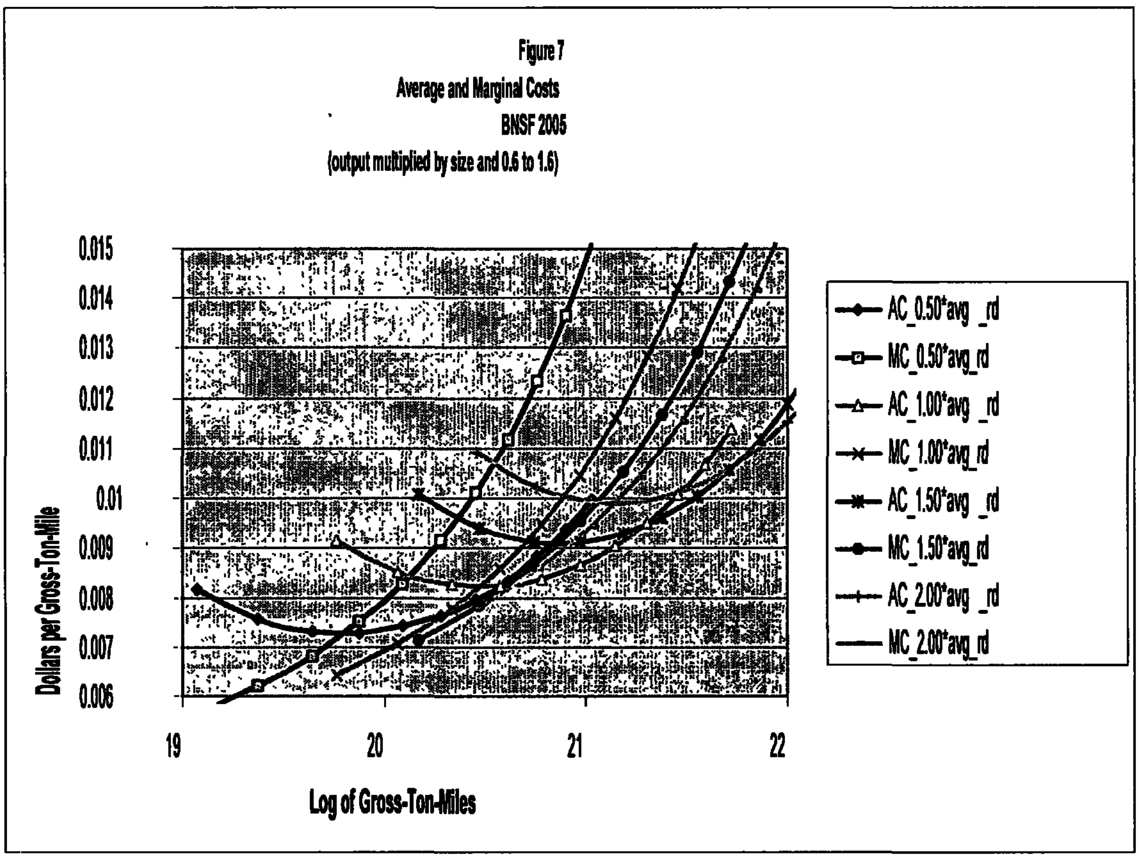
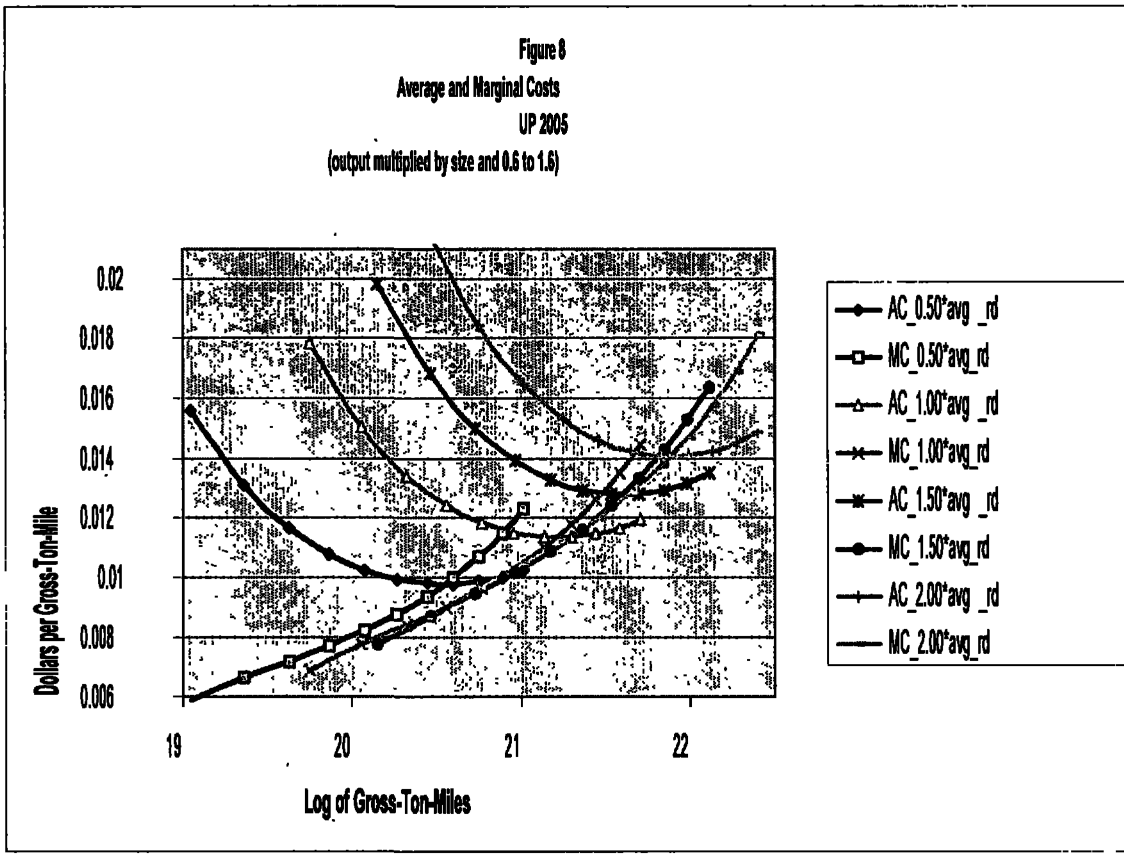


Figure 7
Average and Marginal Costs
BNSF 2005
(output multiplied by size and 0.6 to 1.6)

UP

The Union Pacific system, like the BNSF is in the area of diseconomies of scale. However, there appears to be some range where the UP can continue to handle traffic and gain economies of density prior to the point where marginal cost rises above average cost.



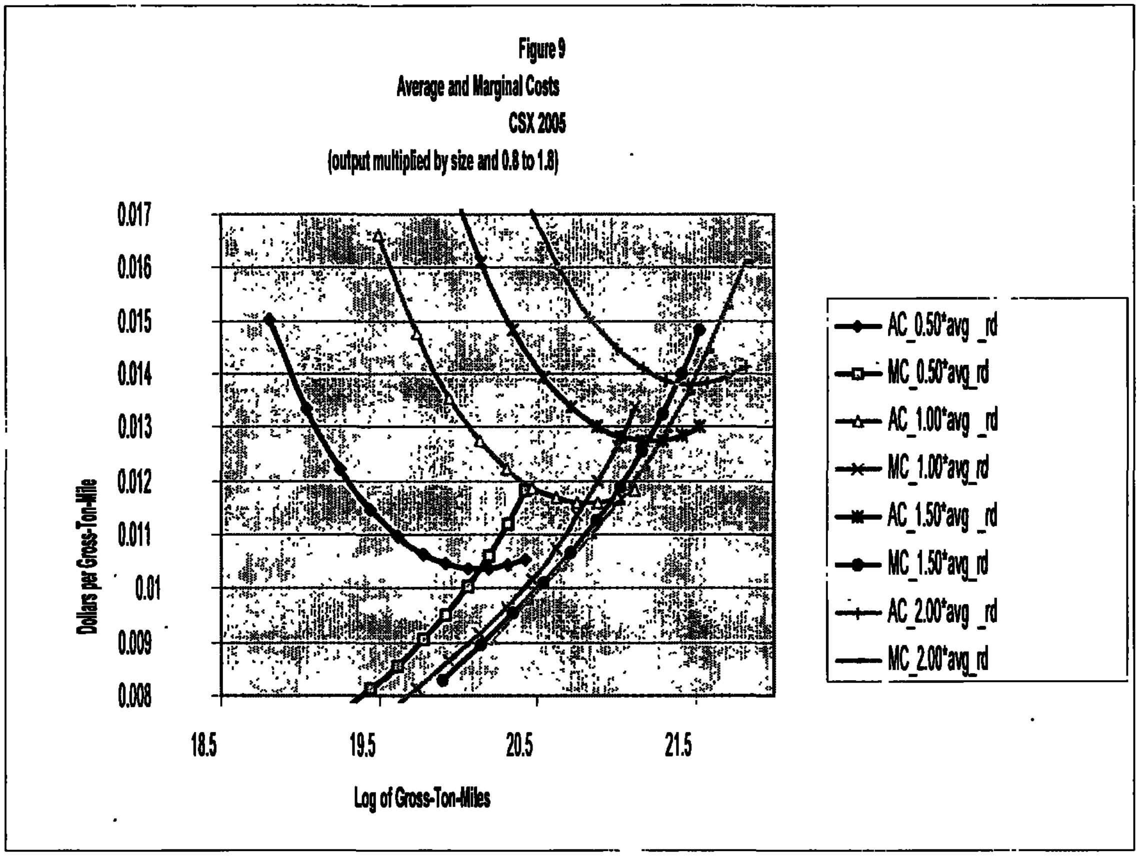
The Big Eastern Railroads

The model indicates that for the two big eastern railroads, the Norfolk Southern and the CSX Transportation system the results are very similar. As Figures 9 and 10 demonstrate, both of these railroads appear to be in the area of diseconomies of scale. However, there are significant economies of density that may be gained by using the track and equipment more intensively. To demonstrate this, the simulation range for the eastern and smaller railroads was changed from 0.6 to 1.6 times average traffic levels to 0.8 to 1.8 times average traffic levels.

CSX

The CSX Transportation system, according to the model, and shown in Figure 10, is also in an area of its cost structure where significant gains may be made to traffic density. Marginal cost does not increase above average cost until traffic levels have increased by more than 50% above the average 2005 levels. Thus, at the estimated level of the capital stock, increases in traffic volume will lower average costs even though diseconomies of scale are evident.

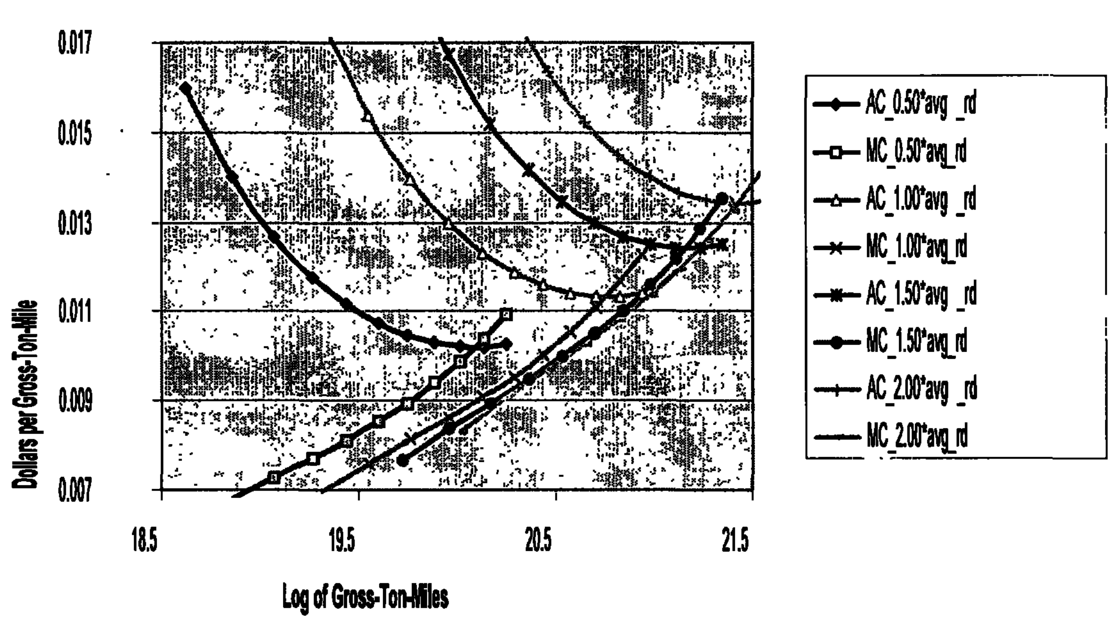
NS



Like for CSX, the model indicates that the Norfolk Southern system has a great deal to gain by increasing density on the existing system. While diseconomies of scale are the case, marginal cost is seen to not cross average cost until average traffic has increases by over 60% from its current (2005) level so that economies to density appear to be significant.

The Three Smaller Railroads

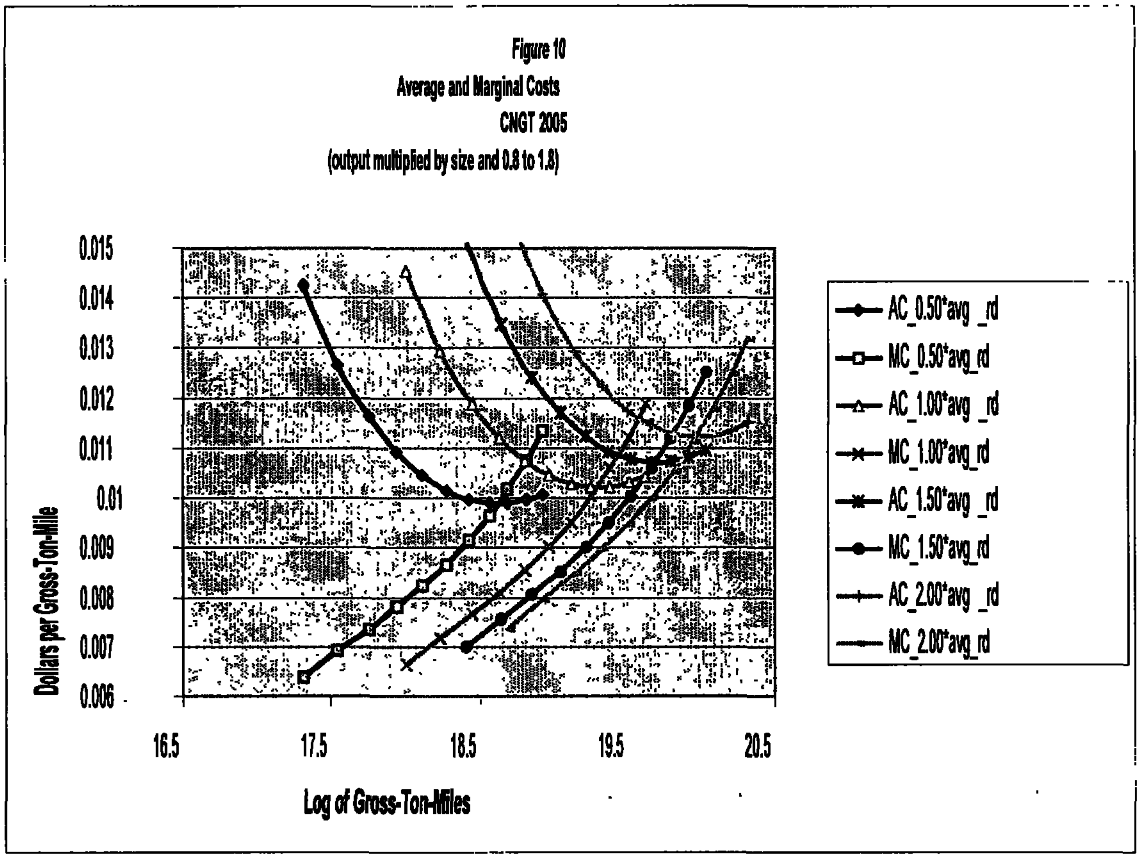
Figure 10
Average and Marginal Costs
NS 2005
(Output multiplied by size and .08 to 1.8)



Of the three smaller railroads, two, the Kansas City Southern and the Soo Line appear to have the potential to gain from economies of scale. The third, the CNGT appears to be at or in the range of diseconomies of scale but this may be due to a data anomaly.

CNGT

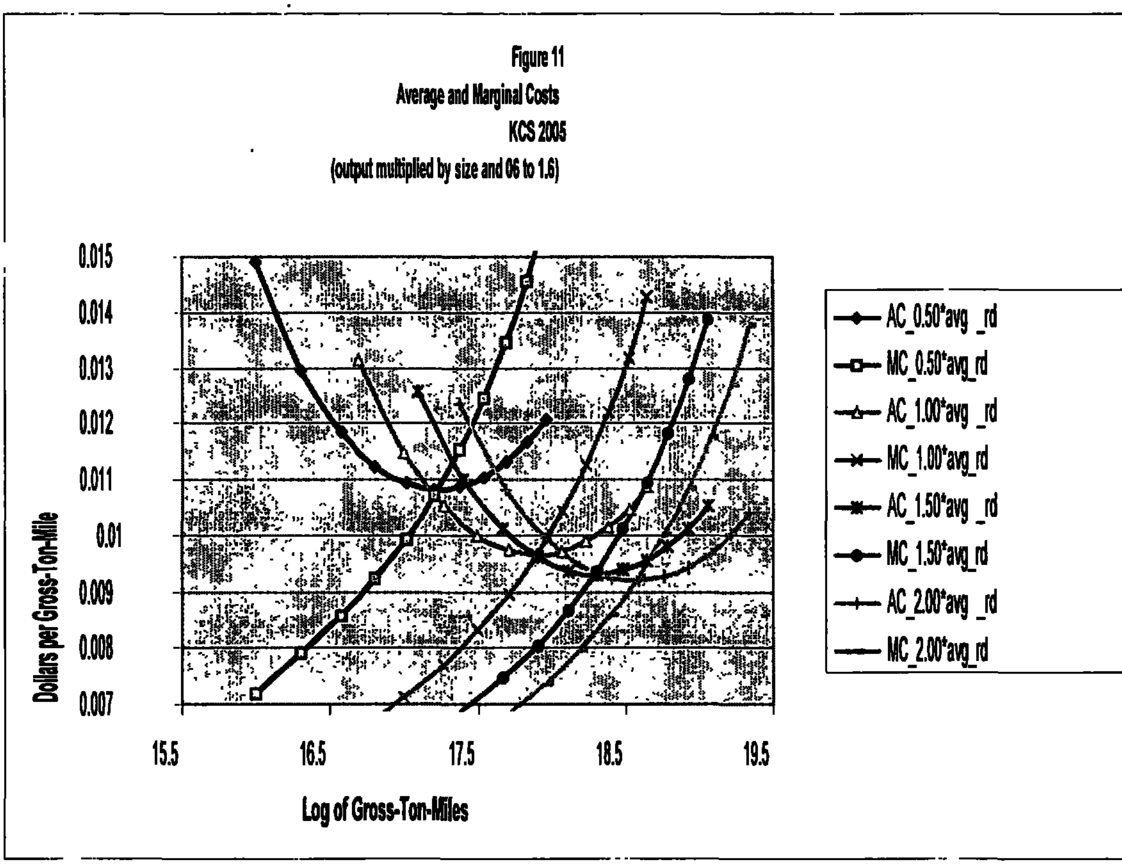
The CNGT system was formed as an accounting combination of two Canadian National owned railroads, the Illinois Central and the Grand Trunk. The combined railroad is much different from the other railroads in the sample in terms of the ratio of roadway capital to equipment capital. Where other railroads have a ratio of between 2.5:1 and 3:1 roadway to



equipment capital, the CNGT has a ratio of approximately 5:1. This somewhat biases the cost comparisons. Even in this case, the CNGT appears to have experienced only minimal dis-economies of scale and has significant density economies available. Simulations indicate that were the capital ratio close to the rest of the industry, economies of scale would exist.

KCS

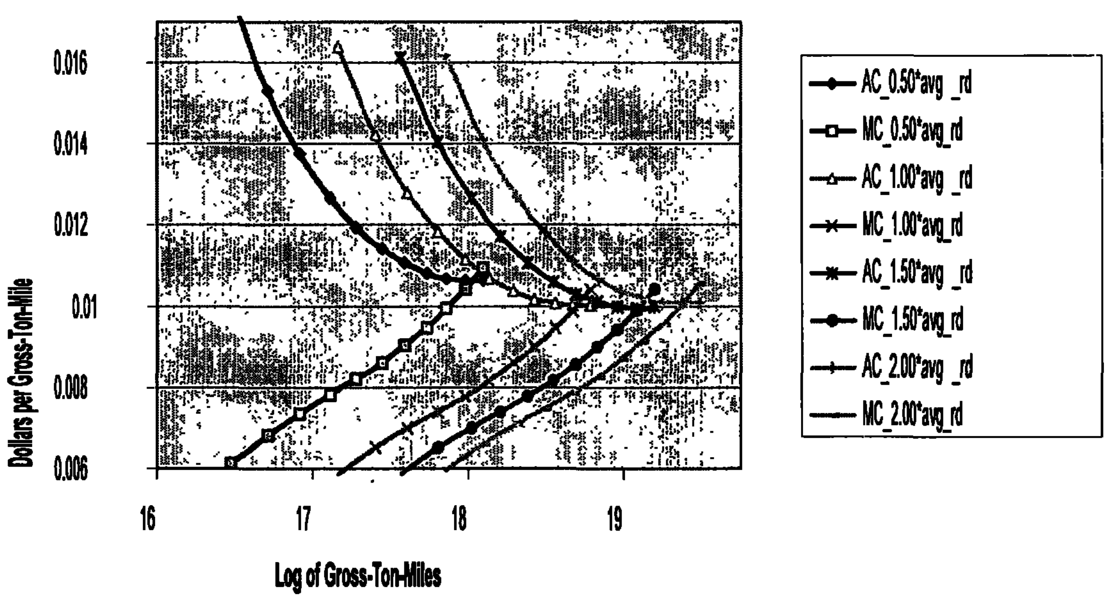
As shown in Figure 11, the Kansas City Southern is expected to have economies of scale available at least up to twice (or more) its current size. However, at current traffic levels, the railroad is very close to the minimum of average cost so that while there are some economies to density still available they are relatively small. Simulation of output levels for the KCS was between 0.6 and 1.6 times current traffic levels.



SOO Line

The Soo line is like the KCS in that it is a much smaller railroad than either the two big eastern or two big western railroads. The simulation indicates that given the current estimated capital stock levels for the firm, there are both economies of scale and density available.

Figure 12
Average and Marginal Costs
SOO 2005
(output multiplied by size and 0.8 to 1.8)



CONCLUSIONS AND POLICY IMPLICATIONS

The research presented here has several important implications in terms of costing of railroad traffic. First, the model demonstrates that, the railroad industry, which was assumed to have significant economies of scale during the period prior to and immediately following deregulation was accurately described. However, in the subsequent period, with mergers between firms and general moves toward a more efficient network, the industry as a whole has exhausted the potential for economies of scale. The optimal size (long-run) of a railroad firm appears to be in the 21,000 to 25,000 mile- of-road-operated range and has been in that range since at least 1976. Four of the railroads, two in the east and two in the west, have surpassed the optimal size. Thus, any merger that might occur to create a trans-continental railroad must be considered economically problematic.

A second result obtained from the analysis is that while economies of scale may have been exhausted, economies of density still appear to remain for the majority of rail firms. Only the BNSF appears to have been able to develop enough traffic to push marginal costs above average costs. While mergers may not be economically advisable, actins on the part of the firm to generate more traffic on their existing networks should allow marginal costs to rise as average costs are falling. It should be noted, however, that the simulation assumed that the changes in traffic levels occurred at a constant ratio to the existing traffic carried by each railroad (and likewise for the industry simulations). Any variations in type of traffic will have slightly differential effects as the values of the five intermediate output measures vary.

Finally, the current model is not designed to be the final word on rail costing. Several modifications toward a multi-level model as suggested by Bereskin (1983) may in fact be appropriate in order to give even more flexibility to rail costing. A bi-level model along these lines would allow for further examination of where productivity is gained and could yield suggestions as to how the industry might become more efficient.

Selected References

Association of American Railroads. *Analysis of Class I Railroads*, Years 1983-2005.

Association of American Railroads. *AAR Railroad Cost Indexes*, Years 1983-2006.

Association of American Railroads. *Railroad Equipment Report*, 2005.

Association of American Railroads. *Railroad Facts*, 2006.

Barbara, Anthony; C. M. Grimm; K. A. Phillips; L. J. Selzer; "Railroad Cost Structure -- Revisited." *Journal or the Transportation Research Forum* 27(1), (1987): 237-244

Bereskin, C. Gregory. *A Bi-level Model of United States Railroad Costs* ; Dissertation(Ph.D.) University of Missouri-Columbia (1983)

Bereskin, C. Gregory. "Econometric Estimation of Post-Deregulation Railway Productivity Growth." *Transportation Journal* 35(4), (1996): 34-43.

Bereskin, C. Gregory. "Railroad Capital Stock Changes in the Post-Deregulation Period"; *Journal of the Transportation Research Forum* 46(1), (2007): 95-110.

Bereskin, C. Gregory. "Railroad Economies of Scale, Scope, and Density Revisited"; Paper submitted to the *Journal of the Transportation Research Forum.*

Bitzen, J. D. and T. E. Keeler. "Productivity Growth and Some of Its Determinants in Deregulated U.S. Railroad Industry." *Southern Economic Journal* 70 (2), (2003): 232-253.

Caves, Douglas W.; L. R. Christensen, and J. A. Swanson. "Productivity in U.S. Railroads, 1951-1974." *Bell Journal of Economics* Spring, (1980): 166-181.

Caves, Douglas W.; L. R. Christensen, and J. A. Swanson. "The High Cost of Regulating U.S. Railroads," *Regulation* January/February, (1981a): 41-46.

Caves, Douglas W., Laurites R Christensen, and Joseph A. Swanson. "Economic Performance in Regulated and Unregulated Environments: A Comparison of U.S. and Canadian Railroads," *Quarterly Journal of Economics* (46), (1981b): 559-581.

Caves, Douglas W.; L. R. Christensen, and J. A. Swanson. "Productivity Growth, Scale Economies and Capacity Utilization in U.S. Railroads. 1955-1974." *American Economic Review* (71), (1981c): 994-1002.

Friedlaender, Ann F. and R. H. Spady.. "Economic Costs and the Uniform Railroad Costing System." Conference on Railroad Costing Procedures: Interstate Commerce Commission, June, 1980

Ivaldi, M. and G. J. McCullough. "Density and Integration Effects on Class I U.S. Freight Railroads," *Journal of Regulatory Economics* 19(2), (2001):161-182.

Lee, Tenpao and C. P. Baumel. "The Cost Structure of the U.S. Railroad Industry Under Deregulation." *Journal of the Transportation Research Forum* 27(1) (1987): 245-253

McCullough, Gerald M. " *"Essays on the Economis Performance of U.S. Freight Railroads Under Deregulation."* Dissertation (Ph.D.), Massachusetts Institute of Technology, 1993.

Oum, Tae Hoon and W. G. Waters II. "A Survey of Recent Developments in Transportation Cost.Function Research.." *The Logistics and Transportation Review* 32(4) (1996): 423-463

Spady, Richard H. *Econometric Estimation of Cost functions for the Regulated Transportation Industries.* New York: Garland Publishing Inc., 1979.

Spady, Richard H. and A. F. Friedlaender.. *Economic Estimation of Cost Functions in the Transportation Industries.* Cambridge: MIT Center for Transportation Studies Report Number 76-13, September, 1976.

Endnotes

1. A major distinction between this analysis and earlier models is in the use of a vector of intermediate output or operating measures to define the railroads' outputs. This compares with the use of either a single output measure or the use of proxy instruments to measure output in earlier studies

2. A fourth price index (for other purchased items) was available, but use of this index created a severe problem of multicollinearity

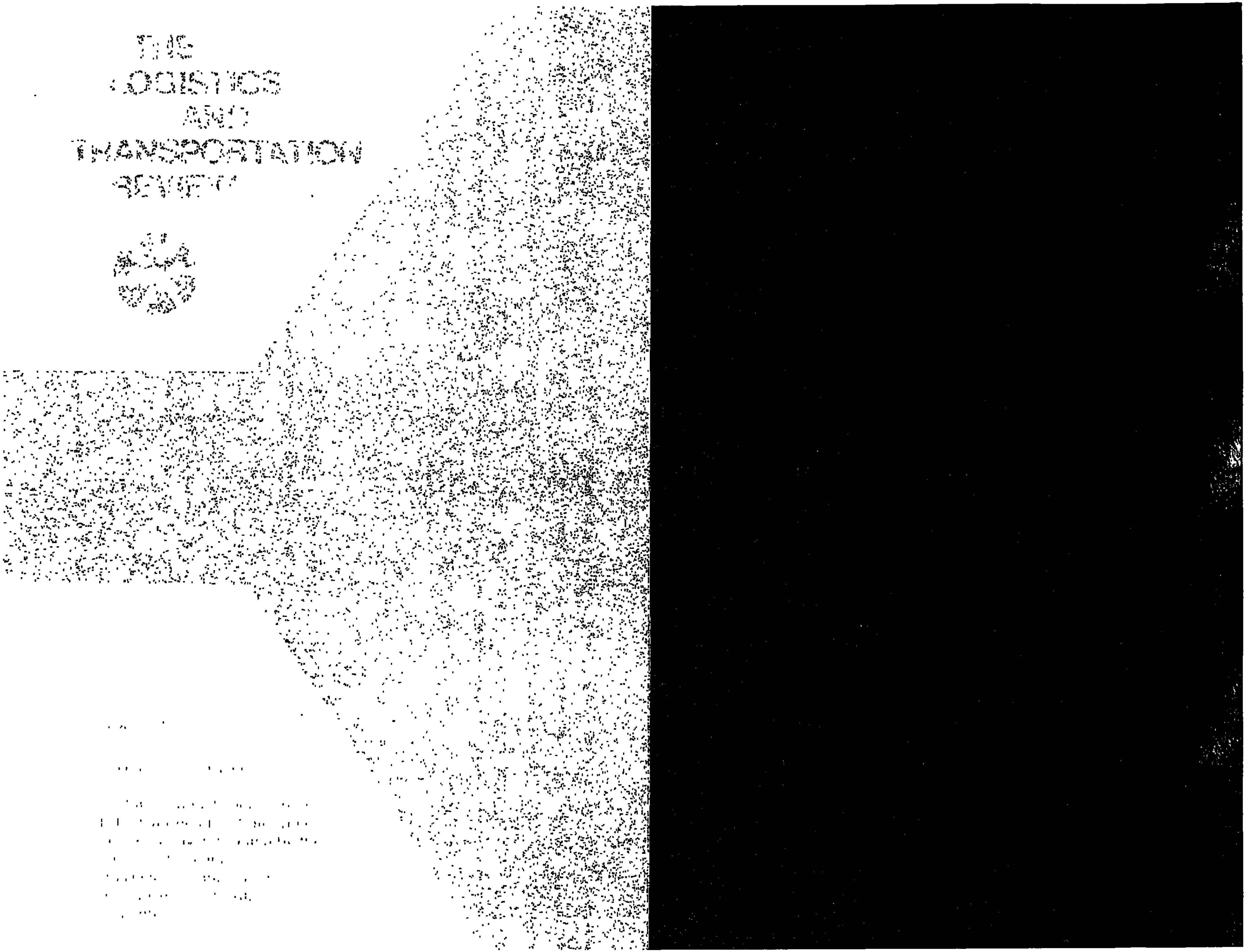
3. Where joint production occurs such as in the railroad industry it is often impossible to get a single measure of output. Frequently, gross-ton-miles or car-miles are used as proxies. Even when these proxy variables are used, it is appropriate to adjust their values for the variations in traffic level such as was done by McCullouch(1993). As used here, the individual intermediate output measures will be applied directly so that specific final outputs can be described by their characteristics. One potential problem is that the measures may actually reflect different operating characteristics for different traffic (a thousand car-miles may consist of one car moving a thousand miles or a thousand cars moving one mile). Unfortunately, given the current state of railroad statistics there is little way around this problem, which occurs in virtually every rail cost model.

4. There is always some concern over specification bias when estimating any cost function. Through use of these five measures, it is expected that the variability in output has been sufficiently explained especially when compared to models that use single measures of output such as gross-ton-miles alone.

Appendix A

RRID	RAILROAD NAME
01	Atchison Topeka and Santa Fe
02	Baltimore and Ohio
03	Bessemer and Lake Erie
04	Boston and Maine
05	Burlington Northern
06	Chesapeake and Ohio
07	Chicago and Northwestern
08	Chicago, Milwaukee, St Paul, and Pacific
09	Chicago, Rock Island, and Pacific
10	Clinchfield
11	Colorado and Southern
12	Conrail
13	Delaware and Hudson
14	Denver Rio Grande and Western
15	Detroit, Toledo, and Ironton
16	Duluth, Massabi, and Iron Range
17	Elgin, Joliet, and Eastern
18	Florida East Coast
19	Fort Worth and Denver
20	Grand Trunk Western
21	Illinois Central Gulf
22	Kansas City Southern
24	Louisville and Nashville
25	Missouri Kansas Texas
26	Missouri Pacific
27	Norfolk and Western
28	Pittsburgh and Lake Erie
29	St. Louis and San Francisco
30	St. Louis Southwestern
31	Seaboard Coast Line
32	Soo Line
33	Southern Pacific
34	Southern Railway System
35	Union Pacific
36	Western Maryland
37	Western Pacific
42	CSX Corporation
43	Norfolk Southern
44	CNGT

THE LOGISTICS AND TRANSPORTATION REVIEW



CN ISSN 0047-4991

The Logistics and Transportation Review, v. 25-2, 1989.

Continues Logistics Review (Berkeley), which was issued 1965-66 as The Logistics Review and Military Logistics Journal.

"An international journal published in Berkeley, California, and in Vancouver, Canada by the Faculty of Commerce and Business Administration, University of British Columbia."

1. Logistics — Periodicals. 2. Transportation — Periodicals. I. British Columbia, University Faculty of Commerce and Business Administration.

U168.L6 355'.41 65-9893

An Econometric Alternative to URCS (Uniform Railroad Costing System)

by C. Gregory Bereskin

ABSTRACT

This paper involves the development and hypothetical testing of an econometric model of railroad costs as an alternative to the URCS. The model follows the proposed URCS framework in terms of data development and the definitions of the various cost sectors. It has, however, been expanded via the application of somewhat less restrictive assumptions concerning the underlying functional properties of costs in order to create a model which more accurately reflects the desired properties of economic cost functions. Among these properties are the potential to represent the unknown underlying cost relationship as a non-linear form.

The results of simulating the model relative to a hypothetical railroad's operations yields reasonable results which are comparable to those developed through alternative costing techniques and, which indicate that additional research into application of econometric techniques into the area of railroad costing models may produce practical and applicable benefits in the area of costing for regulatory purposes.

I. Introduction

Three types of costing methodologies have been generally advocated for the rail industry: the econometric/statistical methods, the allocative accounting methods, and the engineering based methods. Each of these methods may have some of the characteristics of the other two and, if computed accurately, they should generally approach agreement.

The econometric methods are regression based and often relate broadly defined categories of costs to broadly defined categories of outputs. Thus, for example, the cost of transporting commodities between two points might be related to the number of ton-miles involved in the process (ton-miles being a combination of the commodity weight, equipment weight, and the distance involved). Once the model has been created, it is possible to hypothesize that

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the measured relationship will continue to be maintained and to project the cost of other similar movements via a comparison to the examined historic behavior.

The allocative methods of costing are generally accounting system based and involve the allocation of accounting expenses to particular activities. This may be as simple as dividing the total expenses by the total output level in order to obtain an average cost or may be accomplished via more extensive regression analysis in order to obtain allocative factors relative to several output measures. The rail costing methodologies generally advocated by the Interstate Commerce Commission (ICC) and much of the rail industry are of this type.

The engineering methods of costing consist of describing the production process being undertaken, determining how many inputs are being used (or should be used) and computing the total cost as the sum of the costs of the individual inputs. One problem that may develop with these models, and the other methods as well, occurs when the various outputs are characterized by joint production, i.e., when several differing outputs jointly use the same input factors. Such is the case in the transportation industries, where the unique amount of the joint factor to be applies to each individual output may be indeterminate, thus creating uncertainty as to the appropriate cost level to be assigned to each individual service.

An additional problem that frequently occurs in rail costing involves the exact form of the equations used to describe the operations themselves. Duality theory indicates that the attributes that are indicated by the underlying production structure will likewise be indicated within the cost function and vice versa. Thus a costing technology that involves a linear process implicitly assumes that the underlying production process is also linear. Because most of the current regulatory costing models involve linear functions, they may not necessarily be able to accurately display the economies of scale, scope, and density that are frequently hypothesized to exist for the rail industry.

This paper will involve the development of an econometric based model of railroad costs as an alternative to the recently proposed Uniform Rail Costing System (URCS) which is currently under development by the ICC. The model will generally follow the proposed URCS framework in terms of the data used and the definitions of various cost sectors. However, economic assumptions and econometric methods will be applied in order to create a model of rail costs that more accurately reflects the desired economic properties of cost functions.

II. Regulatory Costing Methods

Two regulatory costing methodologies are relevant to this discussion. Rail Form A (RFA) has been the principally accepted costing tool for both the ICC and the Industry since its inception in 1943[1]. RFA is an allocative system where the allocation factors are based on statistical analysis of a cross section of the industry. The Uniform Rail Costing System (URCS), as currently proposed[2], is similar to RFA in the basic methodology of applying statistical analysis to individual expense accounts in order to provide a tool for allocating expenses to an individual process. The proposed URCS is, however, projected to provide a significant advance over RFA in the area of flexibility of use and more precise analysis. Each of these methods is similar also in the general use of a "percent variable" term for allocation purposes, although RFA assumes a constant and equal variability for all railroads while the currently proposed URCS allows for differing variabilities on a railroad by railroad basis.

Rail Form A

Rail Form A is designed to separate total rail expenses into distinct categories based on operational parameters. These expense categories may then be applied toward individual car movements in order to obtain cost estimates based on the parameters of that movement Within this methodology, a number of tables have been constructed to map comparisons of costs both over geographic areas and the individual firms. The costs obtained from RFA (and the URCS) are generally developed as follows:

(1) The individual expense accounts are separated into categories dependent on the type of operation being performed. For example, the Maintenance of Equipment expenses would be divided between running or switching services as was appropriate.

(2) The operationally similar expense accounts are then grouped and the total expense for the group is distributed to the individual car movement parameters based in the types of service units which functionally relate the accounts. Examples of the relationships are the setting of freight train car maintenance as a function of the revenue car miles and the functional relationship of switching expenses to carloads originated or terminated. Expenses for less than car loads are similarly developed

(3) The expenses from each movement are next separated as being either fixed or variable on the basis of a computed percent variable value for the given account grouping. These percent variable estimates are generally obtained through regression analysis on cross-sectional data, although some are set according to apriori knowledge of railroad operations[3]. Where regres-

sion analysis is used, the variability factor is determined, at the industry average output level, as the ratio of the expected variable cost (the total cost as determined from the regression equation when the fixed factors are set to zero) to the total cost as determined at that output level. For each of the individual accounts used to develope the aggregate account grouping, this "percent variable" factor is then used to create an estimate of the part of the account that reflects "variable cost." The variable cost portion of the account is then divided by the value of the service units that was used as the output measure in the regression equation in order to get an estimate of the "variable cost per unit of output."

(4) The individual accounts and their variable cost estimates may then be reaggregated based on the service units associated with the specific traffic under review in order to form an estimate of the total variable costs of the individual shipment as based on the operational parameters of the movement.

Uniform Rail Costing System

The URCS is currently being developed under a mandate of Congress through the Railroad Revitalization and Regulatory Reform Act of 1976 (4-R Act). Under this mandate, the ICC was directed to develop an updated and more comprehensive costing system than RFA. The requirements of this system are further responsive to the costing requirements of the Staggers Rail Act of 1980. In addition, the system is, theoretically, designed to be flexible enough for use by both the shipping public and the railroads in any negotiations outside of the regulatory sphere. The value of this attribute is, of course, dependent upon the accuracy inherent in the system.

The URCS shares a number of methodological attributes with RFA. Among these are its format as an accounting based allocative costing system, the dependence on statistically developed variability estimates[4], the ability to allow some specific user input beyond the carrier average cost structure, the reliance on historical studies to provide information in addition to the annually reported expenses, and the ability to function within the formal regulatory framework as established by previous ICC proceedings.

One of the major advances of the URCS over RFA originates with the more comprehensive accounting system from which it has been developed[5]. Where RFA variability estimates were generally developed by averaging the results of several one-year regressions, the URCS allows for the use of multiple years of data by averaging the observations of up to five years of data. This is claimed to provide a more accurate inclusion of the long-term cost behavior within the variability estimates since short-term costs variations which may be off of the long-run curve are expected to balance each other. One problem

with averaging in this manner is that a great deal of information may be lost concerning year to year fluctuations in costs which may, in reality, be movements along the short-run cost curve. Thus, the variability estimates obtained are expected to be closer to long-run rather than short-run values. An additional potential improvement in the URCS system is that the more disaggregated accounting system allows for a finer breakdown of costs into categories on which variability analysis may be performed.

One additional problem which may develop in the proposed URCS relates to a general concentration on the linear functional form. If the underlying structure is non-linear, the use of linear forms may result in an additional bias for any observations that are removed from the close proximity of the historical observation[6].

III. Economic Models of Railroad Costs

The literature on the economic costs of railroad operations is extensive and can generally be classified into two areas. The variability models, covering much of the pre-1970 research, are primarily concerned with estimating the output elasticity of costs in relation to the fixed and variable factors while the (primarily) post-1970 structural models are concerned with the specification of a model of total costs and generally require the use of non-linear representations of the relationship between the inputs and outputs.

The Cobb-Douglas (C-D) function has frequently been used to represent the production technology of the railroad industry in work undertaken by such authors as Friedlaender (1971), Keeler (1974), Haskenkamp (1976), and Kneafsey (1975)[7]. However, as has been pointed out by Blackorby, Primont, and Russell (1978, p. 315), the C-D function can represent only a completely separable production technology. This, in turn, implies joint production of all outputs. Still, the generalized C-D function has frequently been applied as a computationally tractable model with which it is possible to test various hypotheses concerning the nature of the production process.

In order to examine the nature of rail costs under somewhat less restrictive technological assumption than that allowed by linear or Cobb-Douglas functions, Caves, Christensen, and Swanson (1980, 1981b, 1981C) applied the translog function to a cost model in order to obtain estimates of the growth in total factor productivity. Using data for the years 1951 to 1974, the model related five input classes plus time to four output classes. From this model, the total derivative of the log of cost with respect to time (d(inC)/dt) was interpreted as the rate of growth of total costs. This in turn was divided between changes in the output levels, changes in factor price (and thus relative factor utilization), and shifts in the cost function which are interpreted as productivity changes.

Another major cost model, the Spady-Friedlaender Rail Cost Model (S-F), has been reported in a series of studies performed by Spady and Friedlaender[8]. Each of these studies has involved the development of a generalized cost function for a multiple output production process. Output measures for freight and passenger service have been included in the models. The primary methodological difference between the S-F model and those discussed above is the emphasis on the development of a short-run model. Additionally, since it is desirable that the model avoid any unwanted implied structural restrictions, the S-F model employs the translog functional form. This allows for the testing of hypotheses concerning the structural relationships rather than having them imposed a-priori on the model[9].

Among the primary conclusions drawn from these several studies are the existence of a high degree of substitutability of the input factors, that the linear relationships which are often used in cost models do not appear justified for the rail industry, that it is inappropriate to imply a non-joint technology to rail costs, and that some firms appear to be experiencing output elasticities which are greater than unity.

IV. Developing a Rail Costing Model

From the application of duality, it can be shown that any well-behaved technology may be described equally well via the production or cost functions. The firms involved need only be assumed to be operating efficiently as cost minimizers in order to insure that they are likewise operating as output maximizers. The cost function[10] in a general case will be defined as the function

$$C(Q, P; T) = \text{Min } PX \text{ Subject to } F(X; T) = Q \tag{1}$$

where Q is a vector of output variables, $P = (p_1, p_2, \ldots p_n)$ is a vector of factor input prices such that p_i is the price of factor input x_i, and T is a vector of technological factors. This function must be considered a long-run function as all inputs are assumed to be variable. Since firms are generally not operating in the long-run but rather have some (effectively) fixed factors, the current emphasis will be on short-run analysis.

Without loss of generality, it is possible to assume that the first factor (x_1) is fixed. The short-run variable cost function is then:

$$\overline{C}(Q, \dot{P}, \overline{x}_1; T) = \text{MIN} \sum_{i=2}^{n} p_i x_i \quad \text{Subject to } f(\overline{x}_1, \overline{X}; T) = Q \tag{2}$$

where $\overline{x}_1$ is the fixed factor, $\overline{X}$ is the vector inputs less $\overline{x}_1$, P is the vector of input prices less p_1, and $\overline{C}(Q, \dot{P}, \overline{x}_1; T)$ is the short-run variable cost function. From this relationship it follows directly that short-run total costs may be denoted as:

$$\dot{C}(Q, P, \overline{x}_1; T) = \overline{p}_1 1\, x_1 1 + \overline{C}(Q, P, \overline{x}_1; T) \tag{3}$$

Where $\overline{P}_1\, \overline{x}_1$ is the short run fixed cost.

In order to maintain a similarity to the currently proposed URCS framework, the cost function will be assumed to exhibit strong separability between the various sectors as described within the URCS.

The general cost function with separability will then be written as:

$$\overline{C}(Q, P, \overline{x}_1; T) = \sum_{s=1}^{S} \overline{C}^s(Q, P^s, \overline{x}_j; T) \tag{4}$$

where the C^s are individual sectoral expenditure function, $\overline{C}$ is a short-run variable cost macro function, and the $\overline{x}_j$ are the fixed factor terms. Each of the sectoral functions may in turn be written in the form

$$\overline{C}^s = \overline{C}^s(Q, x_j, p_1^s, p_2^s, \ldots, p_N^s; T). \tag{5}$$

If, however, the price levels of the individual inputs are held constant, the individual sectoral cost sub-functions become:

$$\overline{C}^s = \overline{C}^s(Q, \overline{x}_j; T, P^s). \tag{6}$$

For purposes of this paper, equation (6) will be rewritten as:

$$\overline{C}^s = \overline{C}^s(Q, \overline{x}_j; T) \tag{7}$$

where the variation in prices that occurs over individual periods and across the various firm a will be assumed as part of the vector of technological factors. This is the general form the cost function we will assume within the remainder of this study.

Interfirm and Interperiod Variations

The nature of variation (other than that implied by the structure of the model itself but inclusive of the price related variation) both over time and across firms will be of importance within the model. It is assumed that these variations may be described as the combination of two terms: one relating time to time and a second related to interfirm differences[11].

The time factor results from two sources. First, the development of new methods and equipment will alter the production process for the industry as a whole. Additionally, this term will reflect short-term variations in traffic level which may not be completely accounted for by changes in the production process. This latter case has been discussed by Borts (1960)[12]. Finally, the time related shift will also reflect the level of input prices to the degree that they are constant across the various firms.

The inter-firm variations are accounted for by a second separate term. (For notational simplicity, these terms are included in the vector T and reflect those variations not implicitly included in the model structure.) Among the factors implicitly included in this latter term representing variations between firms, are differences in terrain, climate, management philosophy, and the mix of traffic. Each of these variations will tend to cause the commonly defined output variable to be slightly different across firms[13].

For purposes of simplification the sectoral level variations will be assumed Hicks neutral, allowing each of the sectoral functions to be written

$$(8)\qquad \overline{C}^s = \overline{C}^s(Q, \bar{x}_j; T) = h^s(T) * \overline{C}^s(Q, \bar{x}_j).$$

A further assumption may be made that the time and industry portions of this vector are multiplicative in nature so that the function may be rewritten as:

$$(9)\qquad h^s s(T) = h^s_t(T) * b^s_f(T)$$

where the subscripts t and f refer to time (annual) and the firm respectively.

By substituting (9) and (8) and taking the natural log of (11) the sectoral cost function becomes:

$$(10)\qquad \ln \overline{C}^s = \ln h^s_t(T) + \ln h^s_f(T) + \ln \overline{C}^s(Q, \bar{x}_j).$$

This is the form in which each of the sectoral functions will be estimated. The results of the individual sectoral functions will then be added as allowed under the assumption of complete strong separability in order to obtain a representation of the underlying cost structure.

The Sectoral Representation

Each of the sectors will be represented by an individual translog function. The translog function has been chosen for two reasons. First, as a flexible functional form, it may be shown that the translog is at least an appropriate

second order approximation for an unknown underlying function. Second, the logarithmic structure of the translog will be of use later in determining estimates of the marginal and average variable costs associated with specific traffic levels. Including the factors for inter-firm and inter-period variation as in equation (10) above, it is possible to describe the remaining portion of each sectoral function by its translog representation. Thus, for the s^{th} sector the translog equation form will be given by equation (11):

$$(11)\qquad \ln \overline{C}^s = a_t \ln h^s_t(T) + a_f \ln h^s_f(T) + a_0 + \sum_{j=1}^{J} a_j \ln q_j + \sum_{i=1}^{I} b_i \ln \bar{x}_i + \sum_{j=1}^{J}\sum_{k=1}^{K} d_{jk} \ln q_j \ln q_k + \sum_{i=1}^{I}\sum_{l=1}^{L} e_{il} \ln \bar{x}_i \ln \bar{x}_l + \sum_{j=1}^{J}\sum_{i=1}^{I} f_{ji} \ln q_j \ln \bar{x}_i$$

where symmetry requires that:

$$d_{jk} = d_{kj} \quad \forall\, j,k \in J \times K$$
$$e_{il} = e_{li} \quad \forall\, i,l \in I \times L$$
$$f_{ij} = f_{ji} \quad \forall\, j,k \in I \times J$$

This is the general form in which each of the sectoral models will be denoted. The individual variables in the models will vary, however, as dependent on the characteristics of each sector

V. Data and Estimation

The data source for this study was the ICC's URCS data set for the years 1978-1985 inclusive[14]. The data consisted of sixteen account groupings developed from the Railroads expense data and eleven categories of operating data combinations of which are proxies for the output levels of the various jointly produced transportation services. The data series and sources are described in Table 1 and Table 2. For purposes of data consistency, the ICC has adjusted the expense account levels to constant 1985 dollar levels. In order to maintain the comparative relationship with the ICC's URCS model, the data will be analyzed in its presented form rather than in the raw data form of current dollar expenditure values for each year. The data has been adjusted to constant dollar form by the ICC, allowing the various sectoral models to assume the general form of equation (11) above.

The data included in the model structure does not, however, cover all of the expenses that may be deemed to be variable. Such expense categories as

TABLE 1*
URCS DEPENDENT VARIABLES

Group Name	Expense Account Group	Accounts Included							
RMAINT	Running Track Maintenance	006	010	012	014	016	018	020	022
		025	029						
MAINTOH	Track Maintenance Overhead and Other Equipment Maintenance and Overhead	001	002	003	004	005	024	028	034
		102	109	110	111	112	114	116	117
		124	126	127	129	139	141	142	144
		145	301	307	308	309	310	313	
		314	318	319	321				
RUNWAGE	Running Crew Wages	402	403						
TRANSOH	Transportation Overhead	401	414	415	416	417	418		
RUNFUEL	Transportation Fuel	409	410						
RLOCREP	Road Locomotive Service, Repairs, and Overhead	411	809002		809004		032	101	201
		204	205	206	209	210	214	215	217
TRNINSP	Road Train Inspection	408							
CLWRCK	Wreck Clearing	413							
SWMAINT	Switching Maintenance and Overhead	007	011	013	015	017	019	021	023
		026	113	116	125	128	140	143	146
YARDOP	Yard Operations	420	422	423	424	425	426	427	429
		430	431	432	433	434			
SWWAGE	Switching Crew Wages	421							
YLOCREP	Yard Locomotive Repairs	809001		809003					
CAREXP	Carload Related Expenses	501	502	504	505				
GENADM	General and Administrative Expenses	027	031	304	305	518	519	520	521
		522	523	524	525	526	601	602	603
		604	605	606	607	608	609	610	611
		612	613	616	617	618			
CARREP	Freight Car Repair Expenses	809006	through			809023			
CAROH	Freight Car Repair Overhead Expense	033	220	223	224	225	228	228	229
		233	234	236					

* Interstate Commerce Commission – Bureau of Accounts, Uniform Rail Costing System (December 1982), 1980 Railroad Cost Study, Pg. 3-5.

TABLE 2*
INDEPENDENT VARIABLES*

VARIABLE NAME	DEFINITION	SOURCE
CLOR	Carloads originated and received	QCS, 4/ sum of columns b,d,f,h
CM	Car–Miles, All Trains	OS–A, 5/ line 102
CMPD	Car–Miles, Railroad Owned & Leased Cars, Loaded and Empty	OS–A, Lines 42 and 58
GTMC	Gross–Ton–Miles (Cars, Contents, and Cabooses)	OS–A, Sum of lines 113, 114, and 115.
LRM	Locomotive Unit–Miles, Road Service	OS–A, Line 15
MR	Miles of Road, Total	R–1 6/ Schedule 700, Column d
THW	Train Hours, Way Switching	OS–A, Line 130
THY	Train Hours, Yard Switching	OS–A, Line 131
TM	Train Miles, Running	OS–A, Line 7
TR	Miles of Track, Running	R–1, Schedule 700, sum of columns d,e,f,g
YST	Miles of Track, Yard Switching	R–1, Schedule 700, Column i

* Interstate Commerce Commission Bureau of Accounts, Uniform Rail Costing System (December 1982), 1980 Railroad Cost Study, Pg. 3-16.

locomotive and other equipment ownership costs have not been accounted for here. These expenses may more appropriately be analyzed using techniques other than those which are developed through econometric modeling. In a complete model development, intended for use in either regulatory proceedings or for internal costing of specific traffic, these expenses would be included via a separate costing analysis and subsequently added to the costs as determined by the current methodology of this paper.

The estimation of the parameters for the individual sectoral cost functions involved the used of a panel data set consisting of cross-section of twenty four railroads, each consisting of a six year time series of observations. The use of ordinary least squares estimation was thus subject to question, as it is possible that the error terms could exhibit autocorrelation in the timewise direction, heteroscedasticity in the cross sectional direction, or a combination of both.

The econometric models which have been developed for handling these two potential problems within the panel data set follow two general lines based on the supposition that the problems may be analyzed either as a function of the relationship of the error terms or alternatively via the model specification. The generalized least squares models (such as the error components model) involve the specification and testing of a hypothesized error structure in order to correct for error term related problems. The covariance model, which has been chosen for use here[15], applies dummy variables as proxies for the otherwise unspecified variations within the general framework of ordinary least squares (partially and implicitly correcting for specification bias in the model structure which may have led to the two estimation problems).

When applying the covariance model, it is necessary to test the hypothesis that all of the time-series and cross-sectional groupings may, alternatively, share a common intercept term. This is done via an F test where the results of a direct OLS estimation without the dummy variables is compared to the results of the covariance model estimates. The residual sum of squares is expected to be higher in the OLS model since it will necessarily have fewer parameters due to the implied restriction on the model (the assumption concerning a common intercept term). If the increase in the residual sum of squares when using the OLS method, adjusted for the change in the number of degrees of freedom, is not significantly different from zero, it may be concluded that the restrictions are not inappropriate and that the OLS estimates are acceptable. Otherwise, the covarience model is accepted as appropriate. Results of this test for the sectoral models in this study will be shown in Appendix A. For each of the sectoral equations, the hypothesis of a shared intercept across firms and time periods was rejected.

The Regression results for the estimation of the individual sectoral models other than for the roadway maintenance sector which is shown below are in Appendix A.2 which may be obtained directly from the author. Since the complete translog specification of the sectoral equations involves a significant number of interrelated data series, it was necessary to develop a mechanism for reducing the number of coefficients to a reasonable number where each coefficient was statistically different from zero at the 95% confidence level. The parcing mechanism chosen consisted of starting with the complete translog specification and iteratively removing that data series that was statistically the least different from zero, i.e.: the data series which the lowest estimated t-ratio. In this manner the equations were reduced to a more manageable size

of no more than 20-25 proposed causal variables (exclusive of the dummy variables). As part of this process, individual linear, quadratic, or cross terms may have been deleted from any of the sixteen sectoral equations. For the RMAINT sector, the regression results (t-statistics for the non-dummy variables) are shown in equation (RM-1) below:

(RM-1) LRMAINT =

15.399470	−5.726547 * LTR	−1.835619 * LGTMC * LGTMC
(6.0907)	(−2.2875)	(−2.2625)
−1.678693 * LGTMC * LMR	+0 819420 * LGTMC * LTR	+0 202995 * LGTMC * LLRM
(−2 5717)	(2 0493)	(5.0691)
+4 757738 * LGTMC * LCM	−21 080411 * LMR * LMR	+43.135649 * LMR * LTR
(2 1887)	(−2 1018)	(2.0981)
+1 631372 * LMR * LCM	−22.295596 * LTR * LTR	−0.634656 * LLRM * LTHW
(2.0427)	(−2 1112)	(−4.1699)
−3 319014 * LCM * LCM	+0 497586 * LTHW * LCLOR	
(−2 2694)	(4 2186)	
−0 00209944 * D78	+0 043686 * D79	+0.037341 * D80
+0 076344 * D81	−0 065980 * D82	−0.240227 * D83
−0.079777 * D84	+0 900781 * DBO	−2.446795 * DBM
+0.331048 * DCO	+2.104859 * DCR	−1.410513 * DDH
−2.192648 * DEJE	−1 190361 * DGTW	+0 285448 * DNW
−2.045342 * DFEC	−0.209717 * DICG	−0.191560 * DSCL
−0.335834 * DBN	−0.1.399987 * DDRGW	1.136434 * DKCS
−1.037914 * DMKT	−0.253834 * DMP	−0 739882 * DSSW
−0.194531 * DSOO	−0 176070 * DSP	+0 326660 * DUP
−1.681658 * DWP	−0 232946 * DSOU	

$R^2 = 0.9807$
SSE = 6.604975
DW = 2.0116

The relevant output parameters used in the estimation of this equation were the measures of gross-ton-miles, miles of road, miles of track, locomotive unit-miles, car-miles, train hours in way switching, and number of cars loaded. It can be seen from the equation that a number of the terms were deleted in the parcing process leading to the remaining fourteen non-dummy variables.

VI. Development of Specific Costs

Marginal Costs

Marginal or incremental costs associated with specific rail traffic may be developed in either of two ways. First, the total cost of transportation may be computed for all of the traffic handled during the given period. The incremental traffic may next be added to the traffic base and the new total variable cost of the total traffic handled may be computed. The estimated incremental cost of the traffic in question becomes the difference between the two estimated cost levels. The second method of determining the incremental cost of specific traffic involves the computation of the output elasticity and total differential of the developed cost function. This latter method will be the one applied here as it lends itself to evaluation not only of the incremental costs but also, through several minor assumptions, to the evaluation of average variable costs as well. The conceptual framework of both RFA and the URCS appears to correspond to the use of average variable costs as the percent variable allocation factors are computed via the slope of a line from the vertical intercept of the cost curve to a point on the cost curve, a methodology that is analogous to computing an average cost allocation factor.

For any given sector, (the assumption of strong separability allows the estimates of total sectoral costs to be additive and thus, the incremental and average variable cost estimates for the sectors will also be additive) the total differential of the translog representation of the cost function may be shown to be:

$$(12)\quad d \ln \overline{C}^s = \sum_{j=1}^{J} \frac{\partial \ln \overline{C}^s}{\partial \ln q_j} d \ln q_j + \sum_{i=1}^{I} \frac{\partial \ln \overline{C}^s}{\partial \ln x_i} d \ln \overline{x}_i$$

where technology for a given firm during a given period of time is fixed. As the analysis is primarily concerned with the short run, it is also appropriate to assume initially that the various size related factors are initially fixed as well, so that:

$$(13)\quad d \ln \overline{x}_i = 0 \quad \forall\ i = 1, \ldots, I.$$

The total differential now becomes:

$$(14)\quad d \ln \overline{C}^s = \sum_{j=1}^{J} \frac{\partial \ln \overline{C}^s}{\partial \ln q_j} d \ln q_j$$

For small changes, it may be shown that

$$(15)\quad d \ln \overline{C}^s = \frac{d\ \overline{C}^s}{\overline{C}^s}.$$

Substituting (13) into (14) and solving for $d\ \overline{C}^s$ yields:

$$(16)\quad d \overline{C}^s = \overline{C}^s \left[\sum_{j=1}^{J} \frac{\partial \ln \overline{C}^s}{\partial \ln q_j} d \ln q_j \right]$$

where $d\ \overline{C}^s$ is the incremental cost of rail traffic in the s^{th} sector, where the actual movement of the traffic is characterized by the incremental output measures $dq_1, \ldots, dq_J$. Total incremental cost is obtained by adding the individual sectoral incremental cost values so that:

$$(17)\quad d \overline{C} = \sum_{s=1}^{S} d \overline{C}^s.$$

Average Variable Cost

Average variable costs are computed from the estimate of incremental costs and an estimate of the output elasticity of cost for each of the individual sectors. These estimates are then aggregated (additively) in order to develop the estimate of the total average variable cost of the movement.

One major problem that develops when attempting to determine a level of average variable cost for a movement that is characterized by several different measures is the definition of what is being averaged. For purposes of this paper, it will be assumed that the term average implies that for a specific movement, a hypothetical change in all output measures may be developed such that the percentage change is the same for all of the measures. Thus, the term average will refer to the theoretical equal rate of change in all measures of output

$$(18)\quad d \ln q_1 = d \ln q_2 = \ldots = d \ln q_J.$$

Likewise, so as to approach consistency with the ICC's concept of "long-run" variable costs, the fixed factors will also be assumed to have an equal percentage variation to that of the output measures. ($d \ln \overline{x}_i = d \ln q_j\ \forall\ i,j$). A further assumption that the firm is always operating efficiently implies that the short-run marginal cost is equal to the long-run marginal cost.

Defining the partial elasticities of output and the fixed factors as:

$$(19a)\quad \epsilon_j = \frac{\partial \ln \overline{C}^s}{\partial \ln q_j}$$

and

$$\epsilon_j = \frac{\partial \ln \overline{C}^s}{\partial \ln x_i} \tag{19b}$$

The logarithmic cost function may be restated as:

$$d \ln \overline{C}^s = d \ln q_j \sum_{j=1}^{J} \epsilon_j + d \ln x_i \sum_{i=1}^{I} \epsilon_i. \tag{20}$$

However, by assumption: $d \ln q = d \ln \bar{x}$, so that equation (18) becomes:

$$d \ln \overline{C}^s = d \ln q \left[\sum_{j=1}^{J} \epsilon_j + \sum_{i=1}^{I} \epsilon_i \right] \tag{21}$$

or, simplifying:

$$d \ln \overline{C}^s = d \ln q \left[\epsilon_T \right] \tag{22}$$

Substituting for the logarithmic terms (22) yields:

$$\frac{d \overline{C}^s}{\overline{C}^s} = \frac{d q}{q} \left[\epsilon_T \right] \tag{23}$$

This equation may then be solved for the average variable sectoral cost ($\overline{C}^s/q$).

$$\frac{\overline{C}^s}{q} = \frac{d \overline{C}^s}{d q} / (\epsilon_T) \tag{24}$$

or otherwise:

$$AC^s = MC^s / \epsilon_T. \tag{25}$$

where AC_s is the average variable cost in sector s associated with the movement based on the averaging assumptions, MC^s is an estimate of the marginal cost associated with the particular movement in question, and ϵ_T is the total factor elasticity as developed above. Thus, if it is assumed that the marginal cost (in sector s) of a specific movement is known (or can be developed), the above formula allows computation of an equivalent average cost as based on the above averaging assumptions. These sectoral average costs may then be

aggregated additively in order to arrive at the total "long-run average variable cost."

$$AC = \sum_{s=1}^{S} AC^s \tag{26}$$

It is this value computed by substituting the marginal cost and partial elasticities into equation (24) and aggregating that most closely corresponds to the concept of "long-run variable cost" as developed in both the URCS and RFA.

VII. Application to An Hypothetical Firm

The model developed above may be applied to any of the individual railroad firms in the sample[16]. This is accomplished by specifying the firm and time related dummy variables that are appropriate for each of the individual sectoral cost functions. The actual output measures for the firm in the period in question are likewise applied in order to estimate the sectoral total cost, the partial elasticities relative to the output measures as developed within each of the sectors, the estimated of sectoral marginal and "long-run" average variable costs, and through aggregation the total marginal and "long-run" average variable costs associated with the movement in question. This makes the model useful not only for cost estimation but also for comparative analysis of the cost levels on the various railroads.

Rather than to develop costs for a specific railroad contained in the sample, the costs shown here will be for an hypothetical firm developed as the average of the actual firms in the sample. It is then possible to examine the cost levels of the hypothetical firm on a general basis in order to compare the shape of the developed cost curves to those that would be expected from general economic theory. Additionally, several hypothetical train load movements will be defined to examine the cost levels obtained from the model for traffic of this type. The model is therefore capable of examining not only specific hypothetical movements but also the effects of overall traffic changes.

Firm Definition

The hypothetical firm that will be used for the examples has been developed as an averages of the actual firms in the sample. This firm will be denoted as HYPO1. The values of the various measures of size, output, and cost were obtained as weighted averages of the values of the actual firms, where the weighting factor was the level of gross-ton-miles. Other weighting variables could have been used equally as well, however, gross-ton-miles is generally

TABLE 3
DESCRIPTION OF AN HYPOTHETICAL FIRM

VARIABLE	HYPO1
GTMC	151731082.403
TM	29502.296
LRM	94722.360
CM	2142436.623
THW	192.776
CMPD	2097689.845
CLOR	217.938
THY	963.465
TR	16.100
MR	12.818
YST	3.295
RMAINT	21686.183
MAINTOH	140756.851
RUNWAGE	216193.285
TRANSOH	124005.489
RUNFUEL	190691.671
RLOCREP	138112.798
TRNINSP	15707.376
CLWRCK	3782.453
SWMAINT	36037.453
YARDOP	119324.931
SWWAGE	71724.504
YLOCREP	6961.938
GENADM	269460.774
CAREXP	3381.714
CARREP	64070.244
CAROH	34214.465
D_RR_RM	0.04054216
D_RR_RMO	-0.23074207
D_RR_RW	-0.10691008
D_RR_TOH	-0.05794987
D_RR_RF	-0.04711440
D_RR_RLR	-0.35990920
D_RR_TIN	-0.03062107
D_RR_CLW	1.26231095
D_RR_SM	0.06822808
D_RR_YOP	0.16004906
D_RR_SW	0.06471919
D_RR_YLR	-0.18771150
D_RR_GAD	0.18123374
D_RR_CEX	-1.12185889
D_RR_CRP	-0.04163630
D_RR_COH	-0.24770978

acknowledged as the most frequently applied single variable for use as a unitary measure of rail output. The values of the variables in the model are given in Table 3.

Average and Marginal Costs — An "Average" Movement

In order to demonstrate the nonlinear nature of the cost function, the sectoral models were combined in order to create a model of total cost for the hypothetical firm. The various output measures were then allowed to change in unison via a multiplicative factor in order to examine the effect of changes in traffic levels where no change in the mix of traffic was occurring. In a real situation, the traffic mix would be expected to vary, perhaps substantially, from this assumption as the individual measures of the traffic level will change at decidely different rates reflective of the specific traffic type being handled. However, for purposes of this section all measures will be assumed to move in tandem as per the averaging assumption.

The average variable costs were then determined as the ratio of total costs as predicted by the model to the level of the multiplier representing the changes in traffic level. The shape of the curves would be the same no matter which variable were chosen due to the constant multiplicative nature of the changes. (For example, the various cost measures could be related to gross-ton-miles yielding a measure of cost per GTMC. The shapes of the curve would be the same, however, since GTMC is changing by the multiplicative factor.) The level of marginal costs was likewise determined as the ratio of the change in total cost with respect to a change in the level of the multiplier. Again, any of the other measures of output could have been applied as long as the measure was consistent with the cost measure. The results of this simulation are shown in Figures 1 and 2. The average cost curve is seen to be "U" shaped as is marginal cost, with the marginal cost curve intersecting the average curve from below.

VIII. Costs for Specific Trains

In order to determine the costs associated with a specific traffic movement, it is necessary to describe the movement in terms of specific movement parameters. These parameters are then used to develop the levels of the variables (GTMC, TM, CM, etc.) that have been used in the model. The values of these input variables for four arbitrarily chosen train types are shown in Table 4. The trains correspond to (1) a heavy unit train of 100 cars each of which is assumed to be loaded with 100 tons, (2) a mixed freight with mixed but averaged cargo, (3) an intermodal movement of 100 trailers moving 1000 miles in standard platform cars, and (4) a 1750 mile movement of trailers on light weight 5 platform spine cars. It is most important for the reader to note that these trains have decidedly differing operating parameters designed to be reflective of actual train movements. As such, the cost estimates which are shown here, while not directly reflective of an actual train movement, may be viewed as an approximation of the cost level that would result from the movement of a train with the hypothetical train parameters as indicated in Table 4.

FIGURE 1
TOTAL VARIABLE COST
HYPOTHETICAL FIRM — 1985

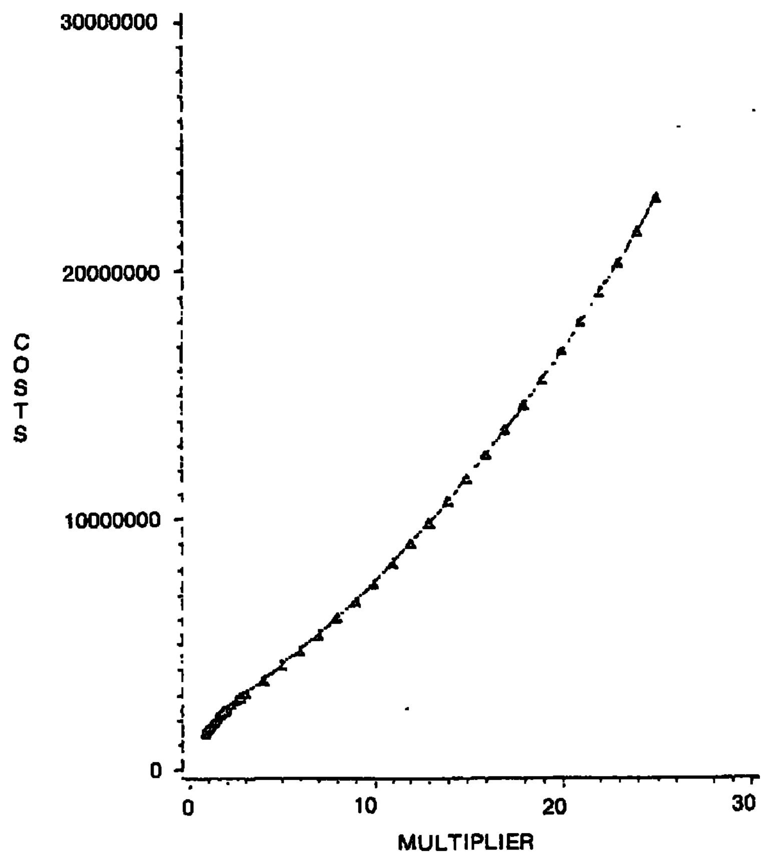
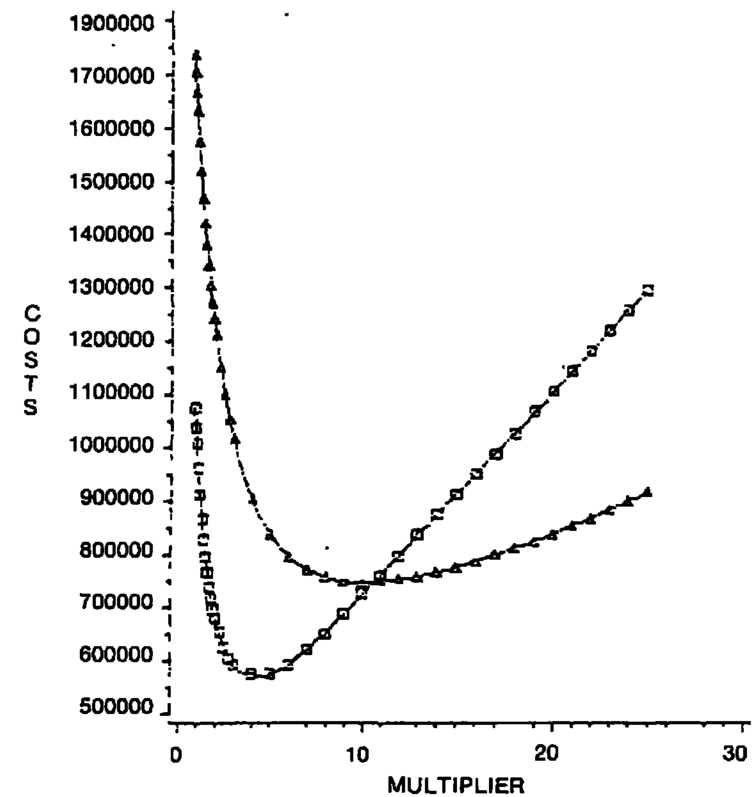


FIGURE 2
AVERAGE AND MARGINAL COSTS
HYPOTHETICAL FIRM — 1985



The individual factors are assumed to represent the total changes in the variable that would result from the addition of the described train to the already existing traffic base. As such, the factors developed may be seen as representative of the incremental changes in output level due to the train and thus allow for the development of an incremental (and average) cost. The

TABLE 4
OPERATING PARAMETERS
SELECTED TRAINS-HYPOTHETICAL RAILROAD 1985

INPUTS	VARIABLE NAME	HEAVY UNIT-TRAIN	MIXED FREIGHT	INTER-MODAL TRAIN 1*	INTER-MODAL TRAIN 2
NUMBER OF CARS	(NO_CARS)	100.00	90.00	50.00	120.00
CARWWEIGHT	(CAR_WT)	31.00	32.00	36.00	14.00
LOAD WEIGHT	(LOAD_WT)	100.00	70.00	56.00	28.00
PERCENT EMPTY RETURN	(P_E_RET)	100.00	45.00	40.00	5 00
NUMBER OF CARS OWNED	(NCAR_OWN)	0.00	60.00	0.00	0.00
NUMBER OF LOCOMOTIVES	(NO_LOCO)	6.00	3.00	3.00	3.00
NUMBER OF CREW	(NO_CREW)	4 00	4.00	4.00	2.00
NUMBER OF CABOOSES	(NO_CABOO)	1.00	1.00	0.00	0.00
CABOOSE WEIGHT	(CABOO_WT)	33.00	33.00	33.00	33.00
ROAD MILEAGE	(ROAD_MI)	1000.00	500.00	1000.00	1750.00
WAY SWITCHING HOURS	(W_SW_HRS)	10.00	20.00	1.00	1.00
YARD SWITCHING HOURS	(Y_SW_HRS)	0.50	20.00	12.00	8.00
ARTICULATED CAR (0,1)	(ART_CAR)	0.0	0.0	0.0	1.0
AXLE FACTOR	(AXL_FCTR)	0.83	0.83	0.83	0.83

* 100 trailers

distance traversed by the train in the movement including any required empty return miles is then:

(27a) $$MR1 = ROAD\_MI / 1000$$

(27b) $$NO\_MILE = MR1 * (P\_E\_RET / 100)$$

For articulated cars, the variable ART_CAR is a (0,1) variable indicating if the car is articulated and the variable AXL_FCTR is the ratio of axles per load of the articulated car relative to the number of axles for the same loads on standard cars such that:

(28a) IF ART_CAR = 1,

$$NO\_CARS1 = AXL\_FCTR * NO\_CARS$$

$$NCAR\_OW1 = AXL\_FCTR * NCAR\_OWN$$

otherwise

(28b) IF ART_CAR = 0,

$$NO\_CARS1 = NO\_CARS$$

$$NCAR\_OW1 = NCAR\_OWN$$

These assumptions will then allow the development of the other model input factors reflective of the changes in the train parameters. These changes are:

(29a) $$DGTMC = ((CAR\_WT * NO\_CARS) * NO\_MILE) + ((LOAD\_WT * NO\_CARS) * MR1) + ((CABOO\_WT * NO\_CABOO) * NO\_MILE)$$

(29b) $$DTM = NO\_MILES$$

(29c) $$DLRM = NO\_LOCO * NO\_MILE$$

(29d) $$DCM = (NO\_CARS1 + NO\_CABOO) * NO\_MILES$$

(29e) $$DTHW = W\_SW\_HRS / 1000$$

(29f) $$DCMPD = NOCAR\_OW1 * NO\_MILE$$

(29g) $$DCLOR = NO\_CAR1 / 1000$$

(29h) $$DTHY = Y\_SW\_HRS / 1000$$

Finally, where the trains are operating under the assumption of reduced crews, the estimated level of crew costs is reduced by 15% for the reduction of each crew member. This factor is not necessarily reflective of actual factors faced by any railroad but has been chosen for use in this paper as indicative of the fact that some reduction in crew costs will occur with crew size though not in proportion to the percentage reduction in crew consist. The exact value of this factor is determined outside the scope of the current model and applied to the specific costing exercise undertaken.

Since in the short-run period over which the incremental cost of the trains under study will be analyzed, the firm size is not generally subject to change, the size related variables have been assumed to be held constant. Thus the changes in the size variables as used in the examples are:

(30a) DMR = 0

(30b) DTR = 0

(30c) DYST = 0.

As an example for the heavy unit-train operating parameters shown in Table 5, the values of the changes in the various output parameters as computed in equations 27 to 30 would be:

(27a) MR1 = 1000.00 / 1000

(27b) NO_MILE = 1000 00 * (1 + (100.00 / 100))

(28b) Since ART_CAR = 0,

NO_CARS1 = 100.00

NCAR_OW1 = 0.00

(29a) DGTMC = ((31.00 * 100.00) * 2000.00)

+ ((100.00 * 100.00) * 1000.00)

+ ((33.00 * 1.00) * 2000.00)

(29b) DTM = 2000.00

(29c) DLRM = 6.00 * 2000.00

(29d) DCM = (100.00 + 1.00) * 2000.00

(29e) DTHW = 10.00 / 1000

(29f) DCMPD = 0.00 * 2000.00

(29g) DCLOR = 100.00 / 1000

(29b) DTHY = 0.50 / 1000

(30a) DMR = 0

(30b) DTR = 0

(30c) DYST = 0.

Combining the definitions of the changes in the output and size related variables as described above and in Table 4, allows for estimation of the incremental (marginal) and average costs of the specific traffic. The results of the simulation for the four trains described in Table 4, are given below in Table 5. (The computer program that was used to obtain the cost estimates for these hypothetical trains may be obtained from the author.)

TABLE 5[17]
COST ESTIMATES FOR SPECIFIC TRAINS
SELECTED TRAINS — HYPOTHETICAL RAILROAD 1985

INPUTS	VARIABLE NAME	HEAVY UNIT-TRAIN	MIXED FREIGHT	INTER-MODAL TRAIN 1*	INTER-MODAL TRAIN 2
TOTAL INCREMENTAL COST	(TMC)	100558.30	38868.71	38494.09	79126.37
INCREMENTAL PER CAR	(TMC_CAR)	1005 58	431.87	384.94	659.39
INCREMENTAL PER TON	(TMC_TON)	10.06	6.17	13.74	23 55
TOTAL AVERAGE VARIABLE	(TAC)	136398.59	44689.79	53058.76	118264.49
AVERAGE COST PER CAR	(TAC_CAR)	1363.99	496.55	530.59	985.36
AVERAGE COST PER TON	(TAC_TON)	13.64	7.09	18.95	35.20

* 100 trailers

These results appear to be reasonable when viewed in terms of the distances traveled and the differences in load, service type, and car type. Likewise the expected relationship between the level of incremental cost and average variable cost that would be indicated by Figure 2 holds for each of the trains leading to further support of the expected economies of scope, scale, and density.

IX. Conclusions

The paper specifies and estimates an econometric model of rail costs consistent with the costing needs of the proposed URCS model and econometric techniques that make the minimum apriori assumptions concerning the true structure of the underlying rail production (and cost) structure. The model gives a cost structure consistent with the generally accepted economic structure of costs, showing the non-linear shape of the underlying relationships.

Furthermore, the model has been shown to yield results for a hypothetical firm that appear to be reasonable in terms of the levels of cost for the types of traffic handled. Because of the complex method of describing, through multiple output measures, the actual level of the traffic carried by each railroad over the period examined, the model may be used to estimate costs for diverse traffic types.

It is important to note that the model developed here does not examine the cost level for all of the variable cost factors associated with the actual movement of traffic. In particular, some of the capital costs associates with equipment ownership have been omitted. As is consistent with other rail costing methods, these costs may be better analyzed directly rather than through an econometric process. With the addition of this sector, the model would be appropriate for costing procedures and would be expected to be no less reasonable than the currently applied allocative costing models where each of the allocative costing factors are determined relative to single measures of output.

Finally, there is some reason to expect that the assumption of strong separability between the various sectors, that allows for sectoral additivity, may be too extreme. It is unlikely that, at least in the long-run, with significant changes in traffic levels, no change will be made in the relative makeup of the sectors or that significant increases in the level of expenditures in one sector will not effect the level of expenditures in other sectors. Examination of this question is, however, beyond the scope of the current paper which has attempted to remain relatively close to the initial URCS sectoral assumptions. In any case, for analysis in a sufficiently short-run period, the strong separability assumption is arguably acceptable.

FOOTNOTES

1. U.S. Congress, Senate, Committee on Interstate Commerce. *Rail Freight Service Costs in the Various Rate Territories of the United States*. S. Doc. 63, 78th Congress, 1st Session, 1943.

2. U.S. Interstate Commerce Commission. "Uniform Rail Costing System: 1980 Railroad Cost Study" (December, 1982) p. 3 2.
Westbrook, Daniel M. "Research Report on Urcs Regression Equations." Delivered to the Interstate Commerce Commission as revised October 17, 1988.

3. Studies to determine the variability factors should be periodically undertaken to verify their continuing appropriateness under changing technology. The latest of these studies for RFA involved data through the year 1972.

4. Where RFA used an average of the results of individual cross-sectional regressions for each of several years data in order to obtain the variability ratios (a methodology for which the statistical properties are unknown), the latest URCS proposals suggest the use of a pooled data regression methodology for which the statistical properties are known.

5. However, in this case the change in the accounting system effectively limits the analysis to the period 1978-1985 as the data from earlier periods is inconsistent with the later data.

6. The use of strictly linear forms may in fact be a step backwards in cost specification technology The final RFA cost study applied a quadratic form in its regression analysis. This does not imply however that the costs themselves were determined to be non-linear as the variability factors determined from the regressions were then held constant for all traffic levels across all firms.

7. The nonlinear nature of the C-D function is often expected to yield a better representation of the underlying cost structure than might be the case with the linear function. However, even with the C-D function, restrictions on the range of potential elasticities may lead to substantial problems in the estimation of costs as related to specific traffic.

8. See Friedlaender and Spady (1980), Spady (1979), and Spady and Friedlaender (1976)

9. The translog function is one of a class of functions which may be shown to provide at least a second order approximation to an arbitrary, twice differentiable, underlying function

10. The presentation of the cost models developed here will generally follow those developed by Spady and Friedlaender (1980).

11. The development of a complete vector of these terms, while theoretically possible, is beyond the scope of the current study. Therefore, they are combined into a single term as discussed here.

12. There is considerable reason to believe that the rail industry is not at a competitive equilibrium. While there is obvious competition for transportation services both internally and from alternative modes, the regulatory history as well as continuing abandonment of trackage would indicate that a long-run stable condition has not been reached. Additionally, there is good reason to believe that the firms, while sharing similar technology, may not be operating on a long-run cost curve but simply moving toward optimal levels of operation given this current (and expected) traffic levels.

13 In this manner, the problems of the regression fallacy has somewhat been compensated for by the model structure.

14. The data is compiled by the Bureau of Accounts of the Interstate Commerce Commission.

15. And which also has been applied in the latest (1989) URCS analysis undertaken by the ICC.

16. An Appendix with a listing of a computerized model (written in SAS) is available from the author.

17 It is important for the reader to note that the trains defined in Table 5 differ substantially both in terms of train makeup and distance traveled and that a direct comparison of the costs given in Table 6 may be inappropriate in the absence of further analysis

SELECTED REFERENCES

Babcock, Michael W. "An Intercity Commodity Transportation Demand Model." *The Journal of Economics of the Missouri Valley Economics Association* V (1979): 175-180.

Balestra, Pietro and Nerlove, Marc. "Pooling Cross Sectional and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas." *Econometrica* 34 (July, 1966): 585-612

Baumol, William J. and Bradford, David F. "Optimal Departures from Marginal Cost Pricing" *American Economic Review* (June, 1970) 265-283.

________, Behling, Burton, N.; Bonbright, James C.; Brozen, Yale, Dean, Joel; Edwards, Ford K.; Hoover, Calvin B; Pegrum, Dudley F.; Roberts, Merrill J.; and Williams, Ernest W. Jr. "The Role of Costs in the Minimum Pricing of Railroad Services." *Journal of Business of the University of Chicago* 35 (October, 1962): 87-96.

Bereskin, C Gregory. "A Bi-Level Model of United States Railroad Costs." Unpublished Ph.D. Dissertation. University of Missouri-Columbia (1983).

Berndt, Ernst R. and Christensen, L.R. "The Translog Function and the Substitution of Equipment, Structures, and Labor in the U.S. Manufacturing, 1929-1968." *Journal of Econometrics* I (1973): 81-114.

________ and ________. "The Internal Structure of Functional Relationships: Separability, Substitution, and Aggregation." *Review of Economic Studies* 40 (1973): 403-410.

Blackorby, Charles, Primont, Daniel; and Russell R. Robert. *Duality Separability, and Functional Structure: Theory and Economic Applications*, New York: Elsevier North Holland Inc., 1978.

________ and Russell, R. Robert. "Functional Structure and the Allen Partial Elasticities of Substitution: An application of Duality Theory." *Review of Economic Studies* 43 (1976); 285-292.

Borts, George H. "Production Relationships in the Railway Industry." *Econometrica* 20 (1952): 71-79.

________. "Statistical Cost Functions — Discussion." *American Economic Review* 48 (May, 1958): 235-238.

________. "Estimation of Rail Cost Functions." *Econometrica* 18 (1960). 108-131.

Braeutigam, Ronald R. "Optimal Pricing with Intermodal Competition." *American Economic Review* 69 March, 1979): 33-49.

________. "An Analysis of Fully Distributed Cost Pricing in Regulated Industries." *Bell Journal of Economics*. (Spring, 1980): 182-196.

Caves, Douglas W.; Christensen, Laurites R.; and Swanson, Joseph A. "Productivity in U.S. Railroads, 1951-1974." *Bell Journal of Economics* (Spring, 1980). 166-181.

________; ________; and ________. "The High Cost of Regulating U.S. Railroads." *Regulation*. (January/ February, 1981a) pp. 41-46.

________; ________; and ________. "Economic Performance in Regulated and Unregulated Environments: A Comparison of U.S. and Canadian Railroads." *Quarterly Journal of Economics* 46 (November, 1981b): 559-581.

________; ________; and ________. "Productivity Growth, Scale Economies and Capacity Utilization in U.S. Railroads. 1955-1974." *American Economic Review*, 71, (December 1981): 994-1002.

Chow, Gregory, C. "Tests of Equality Between Sets of Coefficients in Two Linear Regressions." *Econometrica* 28 (1960): 591-605.

Danzig, Jerry Co.; Rugg, Jerry A.; Williams, John A.; and Hay, William W. *Procedures for Analyzing the Economic Costs of Railroad Roadway for Pricing Purposes*. Washington, D.C. U.S. Department of Transportation, Federal Railroad Administration. January, 1976.

Dhrymes, Phoebus J. "On Devising Unbiased Estimators for the Parameters of the Cobb-Douglas Production Function" *Econometrica* 30 (1962): 297-304.

Eads, George; Nerlove, Marc; and Raduchel, William. "A Long Run Cost Function for the Local Service Airline Industry: An Experiment in Non-Linear Estimation." *Review of Economics and Statistics* 51 (August, 1969): 258-270

Ferguson, A.R. "Empirical Determination of a Multidimensional Marginal Cost Function." *Econometrica* 18 (1950): 217-235.

Fisher, Franklin M. "Tests of Equality Between Sets of Coefficients in Two Linear Regressions: An Expository Note." *Econometrica* 38 (1970): 361-366.

Friedlaender, Ann F. *The Dilemma of Freight Transport Regulation*. Washington, D.C.: The Brookings Institution, 1969.

________. "The Social Costs of Railroad Regulation" *American Economic Review* 61 (May, 1971): 226-234.

________ and Spady, Richard H "Economic Costs and the Uniform Railroad Costing System." *Conference on Railroad Costing Procedures:* Interstate Commerce Commission (June, 1980).

Griliches, Zvi. "Cost Allocation in Railroad Regulation." *Bell Journal of Economies* 3 (Spring, 1972): 26-41.

Hasenkamp, Georg "A Study of Multiple Output Production Functions: Kleins' Railroad Study Revisited." *Journal of Econometrics* 4 (1976): 253-262.

Keeler, Theodore E. "Railroad Costs, Returns to Scale, and Excess Capacity" *Review of Economics and Statistics* (May, 1974): 201-208.

Kneafsey, James T. "Costing in Railroad Operations: A Proposed Methodology." *Studies in Railroad Operations and Economics* 13. United States Department of Transportation, Federal Railroad Administration (March, 1975).

———. *Transportation Economic Analysis.* Lexington, Mass.: Lexington Books, D.C. Heath & Co., 1975.

McFadden, D. "Cost Revenue and Profit Functions" in *Production Economics: A Dual Approach to Theory and Application.* Edited by N. Fuss and D. McFadden. Amsterdam: North Holland Press, 1978.

Meyer, John R. "Some Methodological Aspects of Statistical Costing as Illustrated by the Determination of Rail Passenger Costs" *American Economic Review* 48 (May, 1958): 209-222.

——— and Kraft, Gerald. "The Evaluation of Statistical Costing Techniques as Applied in the Transportation Industry." *American Economic Review* 51 (May, 1961): 313-334.

———; Peck, Merton J.; Stenason, John; and Zwick, Charles. *The Economics of Competition in the Transportation Industries.* Cambridge: Harvard University Press, 1959.

Russell, R.R. "Functional Separability and Partial Elasticities of Substitution." *Review of Economic Studies* 42 (1975): 79-86.

Sato, K. "A Two Level Constant Elasticity of Substitution Production Function." *Review of Economic Studies* 34 (1967): 201-218.

Shephard, Ronald W. *Theory of Cost and Production Functions* Princeton, New Jersey: Princeton University Press, 1970.

Spady, Richard H. *Econometric Estimation of Cost Functions for the Regulated Transportation Industries.* New York: Garland Publishing Inc., 1979.

——— and Friedlaender, Ann F. *Economic Estimation of Cost Functions in the Transportation Industries.* Cambridge: MIT Center for Transportation Studies Report Number 76-13, September, 1976.

Theil, Henri. *Principles of Econometrics.* New York: John Wiley and Sons Inc., 1971.

U.S. Interstate Commerce Commission. "Uniform Rail Costing System. 1980 Railroad Cost Study (December, 1982).

U.S. Interstate Commerce Commission. "Uniform Rail Costing System: 1979 Railroad Cost Study (December, 1979)

U.S. Congress, Senate, Committee on Interstate Commerce. *Rail Freight Service Costs in the Various Rate Territories of the United States* S. Doc. 63, 78th Congress, 1st Session, 1943.

Wales, Terence J. "On the Flexibility of Flexible Forms: An Empirical Approach." *Journal of Econometrics* 5 (1977): 1983-193.

Walters, A.A "Expectations and the Regression Fallacy in Estimating Cost Functions." *Review of Economics and Statistics* 42 (1960): 210-215.

Walters, A.A. "Production and Cost Functions: An Econometric Survey" *Econometrica* 31 (1963): 1-66.

Wilson, George W. "On the Output Unit in Transportation." *Land Economics* 3 (1959): 266-276.

Zellner, Arnold. "An Interesting General Form for a Production Function." *Econometrica* 19 (1951): 188-189.

Accident Involvement and Highway Safety

by Patrick S. McCarthy

ABSTRACT

This paper develops a model which incorporates two aspects of driver behavior that have been ignored previously. First, rather than focusing upon one's speed decision in isolation, the model analyzes one's speed decision relative to mean traffic speed. Second, since the effect of changes in government policy upon highway safety is revealed through its effect upon the likelihood of an accident, accident probability is endogenous to the model. This provides new insight into recent empirical findings regarding the effects of speed and speed variation on highway safety.

1. Introduction

Over the past few years, controversy has risen regarding the relationship between mean traffic speed and highway safety. It has long been believed that average traffic speed is a significant contributor to the fatality rate, a hypothesis which has been theoretically discussed (Peltzman (1975), Blomquist (1986), Graham and Garber (1984), and Zlatoper (1987). However, based upon earlier work by Solomon (1964), which argues that accident rates increase with decreasing traffic uniformity, Lave (1985) estimated a model of fatality rates and demonstrated that when speed variance is included, mean speed is no longer significant. An implication from Lave's work is that, in both theoretical and empirical research, too much weight has been given to speed per se and too little weight to speed variation.

The objective of this analysis is to develop an economic model of driver decision making which differs from previous models in two respects. First, it incorporates Solomon's empirical finding that the probability of accident involvement increases as one's speed diverges from mean traffic speed. Second, it recognizes that, with respect to highway safety, an individual's

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Financial support for the research reported in this paper was provided by the AAA Foundation for Traffic Safety.

SPRING 2001

TRANSPORTATION JOURNAL™

VOL. 40 / NO.3

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Sequential Estimation of Railroad Costs for Specific Traffic

Abstract

Railroad cost models have been estimated by numerous economists as well as government organizations. Most of the economic models have been aimed at explaining the economic characteristics of the production process rather than applying the models toward the costing of specific traffic. The industry and the government (specifically the Interstate Commerce Commission [ICC] and the current Surface Transportation Board [STB]) have instead been concerned with developing models that can be used for costing specific traffic, having less concern for the economic characteristics of the model. Examples of the latter method include Rail Form A and the more current Uniform Rail Costing System (URCS). Unfortunately, none of these models have been updated since the late 1980s and the estimated parameters may be significantly out of date.

This study involves the development of a model of railroad costs that may be applied toward the costing of specific railroad traffic. The model is estimated sequentially for years 1995-1998 using a set of data on Class I railroad expenditures over the period 1978 to 1998. Specific traffic levels are characterized for four hypothetical train types and marginal cost estimates are obtained for each of these trains. The model and train costs are then re-estimated as if the estimates were accomplished in each of the final years with the data available at that time. The marginal cost estimates for each subsequent model then are compared across the models in order to examine the stability of the cost estimates and costing methodology over time. Individual parameter values are expected to change as the model progresses. However, it is also demonstrated that as time progresses the new estimates give post-facto estimates of traffic costs that are similar to those that were obtained in the earlier year model estimates.

Railroad cost models have been estimated by both economists and government regulatory organizations for more than sixty years. Most of the economic models such as those of Caves, Christensen, and Swanson;[1] Spady and Friedlaender;[2] and Bereskin[3] have concentrated on the shape of the cost function and its implications for productivity growth and economies of scale, scope, and density. Likewise, Oum and Waters[4] have discussed the current status of transportation cost study advances over the last two decades and have described various refinements in the modeling methodology that has allowed researchers to further test for economies of scale and scope as well as productivity growth. All of these studies generally agree in their conclusions that the railroad industry has been achieving productivity gains both over time and through mergers and that rail costs are decidedly non-linear in nature.

Over the same period, the rail industry and the government (specifically the Interstate Commerce Commission [ICC] and the current Surface Transportation Board [STB]) have been concerned with developing models that can be used for costing specific traffic, having less concern for the economic characteristics of the model. Examples of the latter method include Rail Form A and the more current Uniform Rail Costing System (URCS). These models use linear "percent variable" equations to allocate expenses to specific operating activities. Three primary problems exist with these regulatory models. First, the allocative equations apply only one measure of intermediate activity; second, the models are linear in

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The author wishes to thank two anonymous referees for their helpful comments on an earlier version of this article. Of course, any remaining errors or omissions are the author's alone.

nature; and third, neither of these models has been updated since the late 1980s and the estimated parameters may be significantly out of date. McCullough[5] has attacked the problem from a different direction by using instruments created from an aggregation of car-mile types to relate costs to car-miles in order to determine cost characteristics for railroad traffic.

This study involves the development of a model of railroad costs that may be applied toward the costing of specific railroad traffic. The model is estimated sequentially for years 1995-1998 using a set of data on Class I railroad expenditures over the period 1978 to 1998. Specific traffic levels are characterized for four hypothetical train types and marginal (incremental) cost estimates are obtained for each of these trains. The model and train costs are re-estimated as if the estimates were accomplished in each of the final years with the data that were available as of each of these dates. The marginal cost estimates for each subsequent model are then compared across the models to examine the stability of the cost estimates and costing methodology over time. Individual parameter values are expected to vary slightly as the model progresses. It is also demonstrated that as time passes the new estimates give post-facto estimates of traffic costs that are similar to those that were obtained in the earlier year model estimates.

METHODOLOGY

The Cost Function

For purposes of the current analysis, the cost function will be modeled using the translog specification. This is a common procedure in developing economic models of rail costs as the translog is one of a group of functions classified as "flexible functional forms." Under specific assumptions concerning the coefficients, these functional forms may be seen to approximate unknown underlying functions. In its translog form, exclusive of technology, the basic cost function may be written:

(1)

$$\ln C = a_{00} + \sum_{j=1}^{N} a_j \ln Q_j + a_{x_1} \ln x_1 + \sum_{j=1}^{M} a_j \ln P_j^1 + \sum_{i=1}^{N}\sum_{k=1}^{N} b_{ik} \ln Q_i \ln Q_k + \sum_{j=1}^{N} b_{jx_1} \ln Q_j \ln x_1 + \sum_{j=1}^{M} b_{jx_1} \ln x_1 \ln P_j^1 + \sum_{i=1}^{N}\sum_{j=1}^{M} b_{ij} \ln Q_i \ln P_j^1 + \sum_{j=1}^{M}\sum_{m=1}^{M} b_{jm} \ln P_j^1 \ln P_m^1$$

(where $Q = (Q_1, Q_2, \ldots, Q_N)$ is a vector of intermediate measures of output which when combined define the characteristics of the final output,[6] $P_1 = (P_1, P_2, \ldots, P_M)$ is a vector of factor input prices, excluding the price of the fixed factor x_1, such that p_j is the price of factor input x_j, and T is the vector of technological factors.

Technological Variations in the Model

Technological variation (other than that implied by the structure of the model itself) both over time and across firms is of importance in the development and estimation of the model. It is assumed that these variations may be described as the combination of two terms, one relating to time and a second related to inter-firm differences. The time-shift factor is assumed to account for technological changes in the production process that are occurring over time and that are thus directly reflective of the rate of change in productivity.

The inter-firm variations are accounted for through the use of shift parameters on a firm-by-firm basis. For notational simplicity, these terms have been included in a vector "T" and are reflective of the differences in operating philosophy, territory, terrain, local conditions, and the mix of traffic which would cause the commonly defined activity variables to be slightly different across firms, rather than being directly reflective, alone, of the economies that may occur from the combination of firms. The cost function will then be written:

(2) $C \doteq (Q, P^1, x_1; T) = h(T) * C(Q, P^1, x_1)$

A further assumption is that the time and industry portions of this vector are multiplicative in nature so that the technology function may be developed as:

(3) $h(T) = e^{time} * h_f(T)$

where the subscript f refers to the individual firm variable.

By substituting (5) into (4) and taking the natural log of (4) the cost function becomes:

(4) $\ln C = \ln C(Q, P^1, x_1) + \ln h_f(T) + \text{time}$

where shift parameters are applied in an additive manner to the translog cost model.

Use of the translog function requires that certain restrictions are met in order to insure that the cost function is well behaved as required by economic theory. A primary requirement is that the cost function should be linearly homogeneous in input prices. As such, the regression model requires restrictions on the price-related coefficients within the cost equation. These restrictions may be written:

$$\text{(5a)} \quad \sum_{j=1}^{n} a_j = 1$$

$$\text{(5b)} \quad \sum_{j=1}^{M} b_{ij} = 0 \qquad \forall \ i = x_i;\ i=1,\ldots,N;\ j=1,\ldots,M$$

where the a_j terms correspond to the coefficients on the linear price terms of the translog equation and the b_{ij} values are the coefficients for the quadratic price variables in the translog specification. Symmetry conditions indicate that $b_{ij} = b_{ji}$.

The variables included in the model are described in Table 1. Four input prices are included: the prices of labor as measured by wages and supplements, the price of materials and supplies by the materials and supply excluding fuel index, the price of fuel as indicated by the fuel price index, and the price of other items indicated by the AAR's index for other expenses. Output is measured by a combination of intermediate operating measures: gross ton-miles, car-miles, train-miles, locomotive-horsepower-miles, and total-switching-hours. Through the use of five measures of out-

Table 1. Definition of Variables

C = TOT_EXP	Total railroad operating expenses
GTMC	Gross ton-miles of cars, contents, and cabooses for firm f at time t (in millions).
CM	Car-miles for firm f at time t.
TM	Train-miles for firm f at time t.
THP	Thousands of horsepower miles* (locomotive unit miles * average horsepower).
THS	Total switching hours (road-switching + yard switching).
MR	The miles of rail operated by firm f at time t -- a proxy variable for the fixed factors of production.
PF	Price index for fuel (applicable only to the transportation sector).
PWS	Price index for wages and supplement.
PMS	Price index for materials and supplies.
PO	Price index for other operating expenses.
d(firm #):	Firm proxy variable to compensate for inter-firm variation of non-merger firms.***
D_rr_#	Separate dummy variables representing firms where mergers have occurred. Each firm is indicated by a pre-merger number and a post-merger number. Mergers are assumed to have occurred when the reporting entities are changed.
D_rr_sc#	Dummy variable to account for special charges to expenses as taken by a specific railroad in a specific year. Some railroads have booked more than one special charge.
D_pre_83	Dummy variable to account for a change in accounting methods (1983) where assets were revalued and depreciation accounting was instituted.
Time	Time variable for underlying productivity trend experienced over the whole data period.

* Average horsepower values were not available for 1978 and 1979 so the equivalent 1980 values were used as a proxy. Industry average horsepower was used as a proxy where firms disappeared from the data set between 1978 and 1980.

**The natural log of any of the specific mnemonics above is indicated by prefixing with the letter L: For example: LMOW = log (MOW). This convention will be followed throughout the article. Squared terms are indicated by a 2 at the name end while cross terms are indicated by a combination of the two names with the second 'L' deleted. For example, LGTMC * LCM = LGTMCM and LCM * LCM = LCM2.

***The Illinois Central Railroad has been deleted from the sample for the year 1997, a year in which the railroad reported zero switching hours.

put simultaneously, it is expected that the cost differences due to varying traffic patterns may be sufficiently accounted for.[7] As is common in much of the transportation literature, plant size is accounted for by the measure of miles-of-road operated. Road mileage is often acknowledged as one, though not a perfect, measure of capital for the railroads. Development and use of an alternative series is beyond the scope of the current study and, historically in railroad costing, it has been commonly believed that measures such as these are sufficient for regulatory and other purposes.

Development Of Specific Costs

Marginal (Incremental) Costs

Estimates of marginal or incremental costs associated with specific rail traffic as developed here involves the computation of the output elasticity and total differential of the developed cost function. The total differential of the translog representation of the cost function becomes:

$$(6)\quad d\ln C = \sum_{i=1}^{n}\left(\frac{\partial \ln C}{\partial \ln q_i} * d\ln q_i\right) + \frac{\partial \ln C}{\partial \ln x_1^1} * d\ln x_1^1 + \sum_{j=1}^{m}\left(\frac{\partial \ln C}{\partial \ln p_j^1} * d\ln p_j^1\right)$$

where technology for a given firm during a given period of time is fixed. As is expected, the partial derivatives of the firm and time dummy variables (representing technology) with respect to the intermediate measures of firm activity will be zero, indicating technology is fixed in the short run. Likewise, it is also appropriate to assume that the size measure (MR) and input prices are fixed as well, so that:

$$(7)\quad d\ln C - \sum_{i=1}^{n}\left(\frac{\partial \ln C}{\partial \ln q_i} * d\ln q_i\right)$$

For small changes, it may be shown that

$$(8)\quad d\ln C = \frac{dC}{C}$$

Substituting (11) into (9) and solving for dC yields:

$$(9)\quad dC = C\left(\sum_{i=1}^{n}\left(\frac{\partial \ln C}{\partial \ln q_i} * d\ln q_i\right)\right)$$

where dC is the incremental cost of rail traffic, when the actual movement of the traffic is characterized by the incremental intermediate operating measures $dq_1, \ldots, dq_n$ multiplied by the partial elasticity of cost relative to that variable.

Data and Estimation — Private Costs

During the long period of railroad regulation, the Interstate Commerce Commission (ICC) required the railroads to supply information on their costs and expenditures. Following deregulation, the Association of American Railroads (AAR) has continued to maintain many of the data series on railroad operations. This effort provided an unusually valuable data source. The data as collected by the AAR are available through their two publications, "Analysis of Class I Railroads" and the "Railroad Cost Recovery Indexes," which supplies indices of input prices. Using these two sources, a fairly complete picture of rail operations may be developed.

The data are limited to the period 1978 through 1998 due to an accounting change that occurred starting with the 1978 observations. A dummy variable, D_pre_83, has been included to account for a shift that resulted from the 1983 change to Depreciation from Retirement, Replacement, Betterment accounting. An additional data problem involves the shrinking number of railroads as mergers or bankruptcies occurred and as some firms were dropped due to insufficient revenues to remain classified as Class I. Where mergers occurred, dummy variables for the firms prior to and following the merger were included in the model to act as proxies for changing railroad structure. As each merger was concluded, a new dummy variable was created using the railroad name and a higher number. For example, when the Union Pacific added the Missouri Pacific and Western Pacific, the variable D_UP_1 ended and D_UP_2 began. Likewise, a number of special accounting charges were taken over the twenty-one year period. In each year where a firm took a special charge against expenses, this was modeled with a 0,1 dummy variable. The rationale for modeling the charges this way was to allow the remaining variables to operate more freely within the model to explain costs, rather than modifying the data set to reflect charges that may not be directly related to the level of the firm's operations in any given year.

The data set as constituted consisted of twenty-one years of observations with thirty-six firms before consolidation. After consolidation and removal of several firms from the list of Class I railroads due to reduction in comparative revenues, the final year (1998) consisted of data for only nine firms. Constructing the data in this manner gave 421 observations of varying number of firms per year for the twenty-one years, a large enough sample to provide sufficient degrees of freedom for most estimation techniques associated with pooled data.

The model was estimated for the translog functional form (equation 1) of the cost model. In addition to the cost function, Shephard's Lemma was applied to develop factor share equations for fuel, labor (wages and supplements), and other operating expenses.[8] Simultaneous estimation of the cost model and the factor share equation was performed using the full-information-maximum-likelihood algorithm in the Soritec econometric software package. The causal variables consisted of the parameters for gross ton-miles; car-miles; train-miles; thousands-of-horsepower-miles; total-switching-hours; miles-of-road-operated; input price indices for fuel, wages, and supplements, materials and supplies, and other expenses; and the dummy variables representing individual firms, mergers, and special charges. The firm dummies and special charge dummies were not included as quadratic terms in the translog functional relationship but appear as 0,1 shift parameters. The restrictions on the regression equations were required in order to insure linear homogeneity of the input prices within the cost function.[9] Four equivalent models were estimated, one for each of the periods: 1978-1995, 1978-1996, 1978-1997, and 1978-1998. Results of these regressions are too extensive to be included here. They may, however, be obtained from the author by request. The regression results are reasonable for a translog specification. One concern when using the translog form is over the number of variables whose t-statistics indicate a weak level of significance. This is not an uncommon situation when a complete translog function is estimated due to the large number of factors included in the functional form and the general close relationship of the variables, which is expected to cause some degree of multicollinearity. As long as each individual variable (GTMC, TM, CM, etc.) is important and included, the choices for getting desirable t-statistics are limited. One possibility is to individually parse the regression terms until only statistically significant terms remain. This method may cause the translog to lose its validity as an approximation to an unknown underlying function. Since all of the variables are believed to be important cost-related elements in the movement of trains, and the factors as a group were significant to the regression, each of the variables was left in the equation.

A further consideration included in the evaluation of the regression involved the values and signs and sizes of the partial elasticity estimates that resulted from the regression equation. As would be expected, the values of the partial elasticities were each between zero and one, a pattern that is normal and desirable. It must be remembered that none of the variables will work completely independently as, for example, an increase in gross ton-miles will frequently be accompanied by increased car-miles, train-miles, and locomotive-horsepower-miles.

Costs For Specific Trains

In order to determine the costs associated with a specific traffic movement, it is necessary to describe the movement in terms of specific movement parameters. These parameters are then used to develop the levels of the intermediate output measures (GTMC, CM, TM, THP, THS) that have been used in the model. Through variation of the five activity measures, it is possible to simulate a number of different operating scenarios as well as differing trains. Increasing the ratio of gross ton-miles to car-miles indicates a heavy wheel loading, and an increase in horsepower-miles relative to gross ton-miles implies more locomotive power and thus more speed. Any train that has these specific combinations of intermediate measures would be expected to yield the same cost estimates. However, the likelihood of trains with decidedly different make-ups having similar combinations of intermediate measures is low. For example, a unit coal train will have a significantly higher ratio of gross ton-miles to car-miles and train-miles than would an intermodal train. Likewise, a faster intermodal train is expected to have a relatively higher ratio of locomotive-horsepower-miles to gross ton-miles than would a slower moving mixed freight, even though the trailing tonnage may be the same. In this way, the use of the five intermediate output measures allows the specific train types to be evaluated on an individual basis.

Cost estimates are provided below for four types of hypothetical trains. The trains chosen for examination correspond to (1) a heavy unit train, (2) a mixed freight with mixed cargo, (3) an intermodal movement of 120 trailers moving 1,750 miles on articulated spine cars, and (4) a 1,750-mile double-stack container movement on lightweight 5 platform cars. It is important for the reader to note that these trains have decidedly differing operating parameters designed to be reflective of (though not the actual compilation of) actual train movements. As such, the cost estimates shown here, while not directly reflective of an actual train movement, may be viewed as an approximation of the cost level that would result from the movement of a train with the hypothetical train parameters.

The partial elasticities of costs depend on the level of service already being provided. While it is possible to examine the cost estimates for any individual railroad in the sample, it was decided instead (for simplicity) to evaluate the levels of costs for two types of "average" railroads. Each of these railroads was developed by averaging the railroads' operating parameters, mileages, and prices for the years 1995-1998. The difference in the two railroads is that one is defined as the arithmetic average of the actual railroads, while the second is defined using a weighted average of the actual railroad parameters where gross ton-miles is the weighting factor. All of the active Class I railroads were included in each average firm. The primary difference between the two definitions is then that the arithmetic average firm is closer to a midline smaller railroad, while the geometric average firm more closely approximates the larger railroads. Characteristics of the firms' operating parameters for 1998 are indicated in Table 2.

The primary benefit of using two railroad definitions is that by using the geometric weight it is possible to examine the behavior of costs as total traffic and route density increases with both railroad size and volume. Results obtained in simulating the train scenarios for the two railroad definitions indicate that some economies exist to railroad size and density. The geometric average railroad in 1998 is approximately 96 percent larger in terms of road-mileage yet carries between 107 and 120 percent more traffic than the arithmetic average railroad, depending on the intermediate output measure chosen. Since much research has indicated that railroads experience some (though not great) economies of size, scale, and density, the cost estimates for the larger firm are expected to be below those of the smaller firm. Cost estimates for various train definitions as shown below are, as expected, less when the same incremental traffic is carried on the geometric average railroad as compared to the arithmetic average railroad, indicating some returns to firm size and traffic density.

For each of the operating scenarios using each of the hypothetical average railroads, the cost estimates are given in tabular form. The results were obtained for both types of average railroad for all of the years 1995-1998. The partial elasticity estimates used in determining each of the costs are given in Table 3, for each of the years. As may be expected, the partial elasticity estimates show some variation both

Table 2. Definition of Railroad Operating Parameters, 1998 and Percent Increase of "Geometric Average Railroad" over "Arithmetic Average Railroad"

	Arith. Avg.	Railroad	Geom. Avg.	Railroad	Percent	Increase
	Total	Per Mile of Road	Total	Per Mile of Road	Total	Per Mile of Road
Gross ton-miles*1000	291492000	25636.94	626911000	36266.98	115.070	41.464
Car-miles *1000	3628600	319.14	7709310	445.99	112.460	39.747
Train-miles	52771900	4641.33	109655000	6343.57	107.791	36.676
Thousand-horsepower-miles	447846000	39388.39	983237000	56880.54	119.548	44.409
Total-switching-hours	1615130	142.05	2986380	172.76	84.900	21.620
Miles-of-road	13368		26253		96.382	

Table 3a. Partial Elasticity Estimates - Arithmetic Average Railroad Activity Measures, Mileage, and Prices

Average Railroad year	G-T-M 98 Model	G-T-M 97 Model	G-T-M 96 Model	G-T-M 95 Model	C-M 98 Model	C-M 97Model	C-M 96Model	C-M 95 Model
1995	0.251885	0.342744	0.267370	0.379075	0.022082	0.001044	0.045420	0.020322
1996	0.254148	0.349715	0.270643		0.017346	-0.007070	0.039869	
1997	0.231768	0.328132			0.021167	-0.005099		
1998	0.234908				0.025279			

Average Railroad year	T-M 98 Model	T-M 97 Model	T-M 96 Model	T-M 95 Model	T-H-P 98 Model	T-H-P 97 Model	T-H-P 96 Model	T-H-P 95 Model
1995	0.192253	0.124347	0.151713	0.165859	0.090580	0.150457	0.166703	0.146929
1996	0.200855	0.131989	0.159620		0.082154	0.144441	0.160557	
1997	0.211101	0.141654			0.077589	0.141589		
1998	0.202513				0.078112			

Average Railroad year	T-H-S 98 Model	T-H-S 97 Model	T-H-S 96 Model	T-H-S 95 Model	M-R 98 Model	M-R 97 Model	M-R 96 Model	M-R 95 Model
1995	0.019007	0.016613	0.017151	0.014203	0.367988	0.387977	0.311458	0.360432
1996	0.019116	0.016874	0.017086		0.381372	0.397507	0.320641	
1997	0.020710	0.018238			0.407863	0.425691		
1998	0.020975				0.393608			

Average Railroad year	P-F 98 Model	P-F 97 Model	P-F 96 Model	P-F 95 Model	P-WS 98 Model	P-WS 97 Model	P-WS 96 Model	P-WS 95 Model
1995	0.079758	0.079758	0.079992	0.079900	0.759014	0.786580	0.776978	0.786441
1996	0.092067	0.092083	0.092426		0.758831	0.786490	0.777133	
1997	0.091170	0.091184			0.759223	0.787228		
1998	0.072285				0.756148			

Average Railroad year	P-O 98 Model	P-O 97 Model	P-O 96 Model	P-O 95 Model	P-MS 98 Model	P-MS 97 Model	P-MS 96 Model	P-MS 95 Model
1995	0.013695	0.007225	0.035071	0.060774	0.147534	0.126437	0.107959	0.072886
1996	0.003980	-0.002277	0.025225		0.145123	0.123704	0.105216	
1997	0.007083	0.000684			0.142525	0.120905		
1998	0.032264				0.139303			

Table 3b. Partial Elasticity Estimates - Geometric Average Railroad Activity Measures, Mileage, and Prices

Average		G-T-M				C-M		
Railroad	98 Model	97 Model	96 Model	95 Model	98 Model	97 Model	96 Model	95 Model
1995	0.229101	0.330702	0.245291	0.380072	0.021881	-0.007908	0.044235	0.009653
1996	0.238037	0.346969	0.254769		0.010673	-0.023203	0.030959	
1997	0.214954	0.324859			0.011664	-0.023538		
1998	0.213669				0.015690			

Average		T-M				T-H-P		
Railroad	98 Model	97 Model	96 Model	95 Model	98 Model	97 Model	96 Model	95 Model
1995	0.226051	0.156576	0.179038	0.184187	0.056679	0.122795	0.143595	0.132656
1996	0.243627	0.177358	0.198067		0.036957	0.104422	0.126487	
1997	0.257035	0.193022			0.030866	0.098693		
1998	0.253272				0.027763			

Average		T-H-S				M-R		
Railroad	98 Model	97 Model	96 Model	95 Model	98 Model	97 Model	96 Model	95 Model
1995	0.020699	0.018348	0.018492	0.015418	0.431549	0.443911	0.360725	0.423602
1996	0.020723	0.018639	0.018348		0.458047	0.460532	0.379952	
1997	0.022583	0.020226			0.491480	0.493682		
1998	0.023113				0.487217			

Average		P-F				P-WS		
Railroad	98 Model	97 Model	96 Model	95 Model	98 Model	97 Model	96 Model	95 Model
1995	0.083038	0.083036	0.083269	0.083175	0.761339	0.789509	0.779412	0.789065
1996	0.096906	0.096911	0.097233		0.759909	0.788249	0.778188	
1997	0.097468	0.097465			0.759175	0.787931		
1998	0.079948				0.756510			

Average		P-O				P-MS		
Railroad	98 Model	97 Model	96 Model	95 Model	98 Model	97 Model	96 Model	95 Model
1995	0.012444	0.005937	0.034111	0.059817	0.143179	0.121518	0.103208	0.067942
1996	0.003422	-0.002788	0.025272		0.139763	0.117629	0.099306	
1997	0.006431	0.000099			0.136926	0.114504		
1998	0.029300				0.134242			

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over the four years and four models as both operating parameters and prices vary. Over the sample period, the average size of the railroads was seen to increase due to mergers, leading to a reduced number of (larger) firms. Likewise, the firms not subject to mergers were actively reducing their mileage while carrying the same or more total traffic, leading to greater densities on the existing structure. The elasticity estimates are relatively stable both over time and model, although there is some tendency toward decrease both over the models and over time as the operating characteristics of the industry changed. Only the partial elasticity estimates for GTMC, CM, TM, THP, and THS are applied in estimating marginal costs as the miles-of-road and input prices are assumed fixed in any given year.

Heavy Unit Train

The heavy unit train used in this example consists of 100 lightweight aluminum cars weighing 26 tons each. Each car is loaded with 105 tons of cargo and will make a 1,000-mile trip with a 100 percent empty return ratio. Four 3,000-horsepower locomotives are used to pull the train. Twelve hours of time is devoted to switching, primarily in loading and unloading the train. The resulting cost estimates are given in Table 4a and b below. Costs for the movement of this train are generally decreasing both over time and over the four models for both the arithmetic and geometric average railroads. The range of incremental cost estimates for the hypothetical movement varies between $4.757 and $7.442 for the arithmetic average railroad and $4.227 and $7.590 for the geometric average railroad. Consistent with the concept of economies of scale, size, and density, the larger road has the lower cost structure.

Mixed Freight Train

The estimated costs for the mixed freight train follow the same general pattern as with the unit train, with the later years and more current estimated model yielding generally lower cost. The example of a mixed freight train applied here will consist of 90 cars weighing 32 tons each. On average, the cars are loaded with 70 tons of cargo and are returned empty 45 percent of the time. Trip length is set at 500 miles. Three locomotives of 3,000 horsepower each will pull the train. The train will be involved with switching operations for an estimated sixteen hours during its movement. Costs for the mixed train are in Table 5a and b. The mixed freight train shows lower cost estimates than the unit train on a ton basis, primarily due to the lower axle loading and lesser total trailing tonnage. Additionally, the mixed freight travels one-half the distance of the unit train. These factors are somewhat compensated for by the lesser horsepower and greater number of switching hours assumed.

Intermodal Train 1 — Spine Cars

Two intermodal trains were hypothesized for comparative purposes. The first intermodal train consists of 120 intermodal trailers weighing, on average, 28 tons for the trailer and contents. The trailers are loaded on lightweight, five-unit articulated spine cars with six wheel-sets per each car of five platforms. The articulated cars are estimated to average 14 tons weight for each platform. The train is projected to travel 1,750 miles with a 5 percent empty return ratio. Because of the higher required speed for intermodal traffic, the trainset will include three locomotives even though the trailing weight is somewhat below that of the mixed freight. Switching time is assumed to total six hours. Estimates of total, marginal, and average costs for this train are listed in Table 6a and b. Like the unit train and the mixed freight, the cost estimates follow a pattern of decreasing costs over both years and models. However, the per-ton estimates for the spine cars train are significantly higher than for the previous two trains. The primary cause of this is the reduced tonnage over which to allocate the costs and the significantly greater mileage (more than triple the mixed freight) over which the train is assumed to travel. Both of these factors tend to increase the per-ton costs.

Intermodal Train 2 — Double Stack

The second intermodal train consists of five-well articulated cars with an average weight of 16 tons per well. Each five-well car has six wheel-sets and is assumed to be loaded with two containers of an average 28 tons each for an average weight of 56 tons per well. Thus, the train consists of 24 cars for a total of 120 wells carrying 240 containers and is assumed

Table 4a. Unit Train Marginal Cost

Year	Arithmetic Average Road				Geometric Average Road			
	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$110,529.00	$141,093.00	$131,588.00	$153,406.00	$98,292.70	$124,754.00	$115,910.00	$156,452.00
1996	$109,822.00	$141,710.00	$130,326.00		$99,057.70	$127,540.00	$114,332.00	
1997	$101,707.00	$133,153.00			$92,792.90	$119,831.00		
1998	$97,432.70				$86,381.60			

Table 4b. Unit Train Marginal Cost per Ton

Year	Arithmetic Average Road				Geometric Average Road			
	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$10.4273	$13.3106	$12.4139	$14.4722	$9.2729	$11.7692	$10.9349	$14.7596
1996	$10.3605	$13.3688	$12.2949		$9.3451	$12.0321	$10.7860	
1997	$9.5950	$12.5616			$8.7541	$11.3048		
1998	$9.1918				$8.1492			

Table 5a. Mixed Freight Train Marginal Cost

Year	Arithmetic Average Road				Geometric Average Road			
	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$31,196.70	$38,061.60	$36,635.40	$41,771.70	$28,401.20	$34,066.60	$32,800.60	$42,809.10
1996	$31,069.10	$38,231.40	$36,321.40		$28,695.20	$34,853.50	$32,407.60	
1997	$29,197.00	$36,252.40			$27,396.70	$33,151.20		
1998	$27,939.90				$25,595.60			

Table 5b. Mixed Freight Train Marginal Cost per Ton

Year	Arithmetic Average Road				Geometric Average Road			
	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$4.9519	$6.0415	$5.8152	$6.6304	$4.5081	$5.4074	$5.2065	$6.7951
1996	$4.9316	$6.0685	$5.7653		$4.5548	$5.5323	$5.1441	
1997	$4.6344	$5.7544			$4.3487	$5.2621		
1998	$4.4349				$4.0628			

Table 6a. Intermodal Train 1 Double-Stack Marginal Cost

Arithmetic Average Road Geometric Average Road

1998	$4.4349				$4.0628			

Table 6a. Intermodal Train 1 Double-Stack Marginal Cost

	Arithmetic				Geometric			
		Average Road					Average Road	
Year	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$58,095.90	$66,572.20	$70,227.40	$74,577.30	$53,584.10	$59,550.30	$63,737.50	$76,032.10
1996	$57,336.30	$66,038.00	$69,019.50		$52,915.60	$59,348.20	$61,656.70	
1997	$55,051.00	$63,650.00			$51,526.90	$57,227.90		
1998	$52,690.50				$48,390.00			

Table 6b. Intermodal Train 1 Double-Stack Marginal Cost per Ton

	Arithmetic				Geometric			
		Average Road					Average Road	
Year	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$17.2905	$19.8132	$20.9010	$22.1956	$15.9476	$17.7233	$18.9695	$22.6286
1996	$17.0644	$19.6542	$20.5415		$15.7487	$17.6632	$18.3502	
1997	$16.3842	$18.9435			$15.3354	$17.0321		
1998	$15.6817				$14.4018			

Table 7a. Intermodal Train 2 Double-Stack Marginal Cost

	Arithmetic				Geometric			
		Average Road					Average Road	
Year	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$82,895.90	$102,303.00	$100,741.00	$112,015.00	$74,284.00	$90,444.00	$89,580.80	$113,981.00
1996	$81,940.30	$102,071.00	$99,286.30		$73,773.40	$91,040.70	$87,188.50	
1997	$77,042.60	$96,969.50			$70,169.90	$86,385.20		
1998	$73,779.10				$65,514.20			

Table 7b. Intermodal Train 2 Double-Stack Marginal Cost per Ton

	Arithmetic				Geometric			
		Average Road					Average Road	
Year	1998 Model	1997 Model	1996 Model	1995 Model	1998 Model	1997 Model	1996 Model	1995 Model
1995	$12.3357	$15.2236	$14.9912	$16.6688	$11.0542	$13.4589	$13.3305	$16.9615
1996	$12.1935	$15.1892	$14.7747		$10.9782	$13.5477	$12.9745	
1997	$11.4647	$14.4300			$10.4420	$12.8549		
1998	$10.9790				$9.7491			

to travel a total of 1,750 miles. An estimated 10 percent empty return ratio is applied to this train, which for the required speed will have a four-locomotive consist. Eight hours of switching time is assumed for the train. The cost estimates for this double-stack train are listed in Table 7a and b. As expected, the double-stack train costs per-ton were significantly below the spine car estimates for a train moving the same distance even though the total costs were higher. The explanation for this is that relative to the weight of the car, the load weight is double that of the spine car model. It is important to note, however, that the loading and unloading of the railcar platforms has not been included in the analysis of intermodal costs. Also excluded has been the cost of any local drayage to the originator or terminal receiver of the traffic.

Conclusions

The research presented here has several important implications in terms of costing of railroad traffic. First, the model demonstrates that, with only minor simplifying assumptions, a general model of total railroad costs may be used to obtain estimates of costs for specific trains. These estimates may be obtained on a railroad-by-railroad basis or for theoretically defined railroads, as are examined here. The costs may be used for analysis of competitive market conditions, analysis of individual train costs, or analysis of changes in road structure on costs. Of particular interest is the significant cost advantage of the long-distance double-stack movement over a similar movement of intermodal highway trailers.

Over time and as the models were re-estimated with each year's new data, the estimates of both partial elasticities and costs per train or per ton were seen to decline. This is consistent with the idea that the railroad industry is gaining economies of scale, scope, and density. The current analysis does not, however, indicate how far the industry may be able to extend these economies either through further mergers or greater operating efficiencies.

Second, the model demonstrates that cost economies do appear to accrue to larger railroads. Under each of the differing trainload scenarios tested, the geometrically weighted railroad that had more track mileage and greater traffic also had lower estimated trainload costs. These are all hypothetical trains on hypothetical railroads, so the actual costs on actual properties are expected to be slightly though not substantially different.

Finally, since costs may be obtained relative to defined operating parameters, the model shows that it is possible to examine individual economies of scale, scope, and density relative to traffic levels in the industry as a whole and on specific railroads as traffic types and operating philosophies change.

The estimates for specific traffic are relatively stable as the model is estimated over subsequent years. The elasticities relative to the various measures of activity do not change substantially over time, allowing the estimates of marginal costs to remain reasonably consistent. As should be expected, the model generates some decrease in estimated costs, on average, as subsequent years are estimated. This is normal, as the operating parameters are changing over the simulation period, and is in line with the changing nature of the industry as the average railroad (whether measured as an arithmetic or geometric average) increases in size and traffic carried. Likewise, the analysis brings into question whether the simple, linear, and decade-old URCS analysis of the ICC and STB may be out of date and no longer valid relative to the changes in the industry. The model further hints that returns to scale, scope, and density do exist within the industry.

A final result from the regression analysis and the estimate of the time coefficient in each of the models indicates that total factor productivity within the industry has been growing at a rate of between 3.474 and 3.693 percent per year, depending on the period modeled: a result that is reasonably consistent with earlier analysis.[10] This also helps to explain some of the cost reduction over the tested time periods.

The current model is not designed to be the final word on rail costing. Several modifications toward a multi-level model as suggested by Bereskin[11] may be appropriate in order to give even more flexibility in the costing of specific rail traffic. A bi-level model along these lines would allow cost analysts to not only estimate costs for specific trains but also examine the relationships among the four primary areas of rail firm activity: maintenance of way, maintenance of equipment, transportation, and general overhead. Thus, it would be possible to

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further examine the relationships among changes in traffic, changes in operating philosophy, and changes in total firm activity on specific areas of rail activity rather than at a total rail cost level.

APPENDIX

RRID	Railroad Name
01	Atchison, Topeka and Santa Fe
02	Baltimore and Ohio
03	Bessemer and Lake Erie
04	Boston and Maine
05	Burlington Northern
06	Chesapeake and Ohio
07	Chicago and North Western
08	Chicago, Milwaukee, St Paul and Pacific
09	Chicago, Rock Island and Pacific
10	Clinchfield
11	Colorado and Southern
12	Conrail
13	Delaware and Hudson
14	Denver and Rio Grande Western
15	Detroit, Toledo and Ironton
16	Duluth, Missabe and Iron Range
17	Elgin, Joliet and Eastern
18	Florida East Coast
19	Fort Worth and Denver
20	Grand Trunk Western
21	Ilinois Central Gulf
22	Kansas City Southern
24	Louisville and Nashville
25	Missouri Kansas Texas
26	Missouri Pacific
27	Norfolk and Western
28	Pittsburgh and Lake Erie
29	St. Louis – San Francisco
30	St. Louis Southwestern
31	Seaboard Coast Line
32	Soo Line
33	Southern Pacific
34	Southern Railway System
35	Union Pacific
36	Western Maryland
37	Western Pacific
42	CSX Transportation
43	Norfolk Southern

ENDNOTES

[1]Douglas W. Caves, Laurites R. Christensen, and Joseph A. Swanson, "Productivity Growth, Scale Economies and Capacity Utilization in U.S. Railroads, 1955-1974." *American Economic Review* 71, (December 1981): pp. 994-1002.

[2]Richard H. Spady, and Ann F. Friedlaender, *Economic Estimation of Cost Functions in the Transportation Industries.* Cambridge: MIT Center for Transportation Studies Report Number 76-13, September, 1976.

[3]C. Gregory Bereskin, *A Bi-Level Model of United States Railroad Costs;* Unpublished Ph.D. dissertation; University of Missouri-Columbia; 1983.

[4]Tae Hoon Oum and W. G. Waters II, "A Survey of Recent Developments in Transportation Cost Function Research." *The Logistics and Transportation Review* 32-4, December, 1996: pp. 423- 463.

[5]Gerald M. McCullough, *Essays on the Economic Performance of U.S. Freight Railroads Under Deregulation,* Unpublished Ph.D. dissertation, Massachusetts Institute of Technology, 1993.

[6] Where joint production occurs, such as in the railroad industry, it is often impossible to get a single measure of output. Frequently, gross ton-miles or car-miles are used as proxies. Even when these proxy variables are used, it is appropriate to adjust their values for the variations in traffic level such as was done by McCullough (1993). As used here, the individual intermediate output measures will be applied directly so that specific final outputs can be described by their characteristics. One potential problem is that the measures may actually reflect different operating characteristics for different traffic (a thousand car-miles may consist of one car moving a thousand miles or a thousand cars moving one mile). Unfortunately, given the current state of railroad statistics, there is little way around this problem, which occurs in virtually every rail cost model.

[7] There is always some concern over specification bias when estimating any cost function. Through use of these five measures, it is expected that the variability in output has been sufficiently explained, especially when compared to models that use single measures of output such as gross ton-miles alone.

[8] A fourth factor share equation for materials and supplies was implicitly used. However, inclusion of all four factor share equations in a simultaneous equation model would result in exact multicollinearity of the model. Additionally, the regression coefficients for those terms relating to the price variable (P_MS) for materials and supplies are not directly included in the regression results as these were all defined relative to the other price measures in order to enforce the linear homogeneity conditions as specified by equation 8.

[9] The estimation software required that the restrictions be included within the definition of the equations to be estimated. As such, the coefficients on the variables related to the price of materials and supplies are all embedded as linear combinations of other coefficients.

[10] See for example: C. Gregory Bereskin, "Econometric Estimation of Post-Deregulation Railway Productivity Growth." *Transportation Journal,* vol. 35-4, Summer 1996, pp. 34-43.

[11] C. Gregory Bereskin, "Econometric Estimation of Post-Deregulation Railway Productivity Growth." *Transportation Journal,* vol. 35-4, Summer 1996, pp. 34-43.